Ontario

Royal Commission on Matters of Health and Safety Arising from the Use of Asbestos in Ontario

THE TECHNICAL FEASIBILITY AND COST OF CONTROLLING WORKPLACE EXPOSURE TO ASBESTOS FIBRES

A Study Prepared By:

Gordon M. Bragg

Study Series

Study No. 7

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for

The Royal Commission on Matters of Health and Safety

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A Study Prepared By:

Gordon M. Bragg

Department of Mechanical Engineering
University of Waterloo
Waterloo, Ontario
Canada

With the assistance of
R.J. Ward
D.L. Siurna
B.H. Hultin

for

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Acknowledgments

The authors would like to express their thanks to the many industries who volunteered information and allowed access to their plants and to the Ontario Ministry of Labour for allowing access to their files. Their contribution has provided the foundation of this study.

ISBN 0-7743-7311-3

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Abstract

This study reviews the current literature on asbestos dust control and the associated costs. An analysis of control methods and resulting fibre levels existing in Ontario is presented. Factors affecting substitution of asbestos are discussed and current applications of substitutes described. There is a widespread desire to move to more substitutes.

In some situations fibre levels can and have been controlled to the 0.1 f/cc level. These levels of control are most commonly achieved in situations where the dust level is very low even without controls. In other processes controls can produce levels around 1.0 to 0.5 f/cc. These are typically in enclosed continuous manufacturing processes. In processes such as debagging, levels of control below 2 f/cc are extremely difficult to achieve. Attempts to achieve exposure levels at or below 1.0 f/cc would require extensive use of personal protective devices, particularly for maintenance and cleaning personnel.

The increased control measures are more costly and examples are given. There is considerable variation in the ability of industry to develop good controls and smaller establishments are at a disadvantage.

1.0 INTRODUCTION

This study covers both the technical feasibility and cost of controlling workplace exposure to asbestos fibre in Ontario and has been commissioned by the Royal Commission on Matters of Health and Safety Arising from the Use of Asbestos in Ontario.

Asbestos, a widely used naturally occurring mineral, is a designated substance, the most commonly used species of which is the single serpentine variety, chrysotile. Canada is the second largest world producer of raw asbestos, producing 1,421,518 tonnes, or approximately 29% of world production in the year 1979. Only chrysotile fibre is mined in Canada (Statistics Canada, 1980). Of this, approximately 95% is exported, primarily to the United States (Gagan, 1980). Bulk asbestos sells for prices varying from approximately 10 cents to $1.00/lb., depending on the grades and properties required.

Detailed consideration of asbestos' mineralogy, toxicology, monitoring techniques, or extra-Ontario industries will not be pursued in this study. Numerous publications dealing with portions of these topics are available; see the Bibliography (Appendix A) for a representative sampling.

1.1 The Asbestos Industry in Ontario

Prior to detailed analysis of the Ontario asbestos-using/producing industrial situation, a brief description of the size and extent of the Ontario manufacturing industry will be provided.

Total Canadian consumption of asbestos in 1977 was 56,600 tonnes. An additional 1,930 tonnes of different types of asbestos were also imported, mainly specialized forms of chrysotile from the U.S.A. Of this, Ontario industries consumed 22,700 tonnes but approximately one-half of this was used at the Johns-Manville Port Union plant which is now closed. We estimate that 1981 Ontario usage was approximately 7,700 - 8,200 tonnes and that 1980 usage was 8100 - 8600 tonnes. These numbers are based upon discussions with producers and users but exact figures are not available. For comparison, United States' consumption is reported as being 770,000 tonnes per year for 1976 (Daly, et al., 1976).

Fifteen companies are identified by the Ontario Ministry of Labour as being major Ontario asbestos product manufacturers in the appendix of a submission made to the Royal Commission: see Appendix F - Table 1. Excluded from this list is the one (small) mining operation known to be in operation currently. Mining and milling of asbestos in Ontario accounts for less than 2% of Canadian production (Charlebois, 1978). As indicated in Appendix F - Table 1, four of these fifteen companies are either no longer in business in Ontario or claim to no longer handle any asbestos. Of the remaining, many are experiencing declining demand for asbestos-containing products, and several have quoted asbestos sales as being on the order of 1 to 10% of their sales volume. The Ontario Ministry of Labour listing has been augmented by the addition of five companies (see Appendix F - Table 2) extracted from a Statistics Canada report and by a list of companies under medical surveillance by the Occupational Health

Branch. Many of these companies are no longer active in asbestos manufacturing and many others have significantly reduced asbestos usage.

With the closing of Johns-Manville manufacturing operations in Ontario as well as the Bendix Automotive business concerns in Windsor in 1980 (Bendix submission to the Royal Commission), the major product manufacturers in Ontario would, then, seem to consist of:

- friction products	4500	tonnes/year of asbestos fibre input
- floor tile	1000	
- gaskets & packings	1250	
- caulking, sealants coatings & paints	600	
- plastics	400	
- acetylene cylinders	180	
- insulators	100	
	8030	

The information in this list was compiled from 1981 figures obtained from identified users and does not include a number of industries which use small quantities.

All contacted companies stated that they used chrysotile only and most intend to remove asbestos from their products within 10 years. The specialized products which are exceptions to this will be discussed later.

Remaining industries involved with asbestos-containing products would then be at the secondary, consumer, and construction industry levels who characteristically receive asbestos already bound or

somehow modified from the raw form. The size of this sector can be inferred from the listing of companies using asbestos and under medical surveillance by the Occupational Health Branch of the Ministry of Labour (Appendix F - Table 3).

1.2 Regulations

To date, no legislated regulations exist specifically detailing allowable maximum asbestos exposure levels in Ontario. Since 1975, however, Ministry of Labour guidelines limiting the 8-hour time-weighted average (TWA) of exposure level to 2.0 f/cc and a ceiling exposure limit to 10 f/cc are being enforced under section 145 of Regulation 692 (R.R.O. 1980) under The Occupational Health and Safety Act for Industrial Establishments; this regulation is applicable to all toxic substances in the workplace environment. As of September 22, 1981, the Occupational Health and Safety Division of the Ministry of Labour has put forward a revised "Proposed Regulation under the Occupational Health and Safety Act, Designated Substance--Asbestos" outlining regulations specific to asbestos that, if enforced, would limit the industrial 40-hour time-weighted average of exposure limit to:

(a) 0.5 f/cc of air for amosite;
(b) 0.2 f/cc of air for crocidolite;
(c) 1.0 f/cc of air for chrysotile;
(d) 1.0 f/cc of air for amosite or crocidolite or amosite and crocidolite when present with other asbestos;

and establishes maximum concentration limits (ceilings) of:

(a) 2.5 f/cc of air for amosite;
(b) 1.0 f/cc of air for crocidolite;
(c) 5.0 f/cc of air for chrysotile;
(d) 5.0 f/cc of air for amosite or crocidolite or amosite and crocidolite when present with other asbestos.

In addition, the proposal outlines codes concerning respiratory equipment, measurement of airborne asbestos fibres, and medical surveillance. These regulations are intended to apply to all concerns in Ontario, including mining, with the exception of the construction industry. A separate regulation proposal is being prepared and will apply to the construction industries; the Ministry of Labour has issued guidelines until regulations are in place in this sector.

This study, then, is intended to examine the costs and the technical feasibility of compliance with the current 2.0 f/cc guideline, if not presently widespread, as well as the cost and feasibility of moving beyond the 2.0 f/cc level to 1, 0.5, and 0.1 f/cc limits for all types of asbestos.

1.3 Measurement of Airborne Asbestos

Within this study, exposure levels referred to in fibres/cc are those measured by the membrane filter (MF) counting technique, except in the case of ambient air levels (background) where the practice has been to use transmission electron microscopy (TEM). The standardized sampling and counting technique to be followed for MF measurement can be found in numerous references including Zumwalde et al. (1977). Since the late 1970's, when it replaced the impinger counting technique, the MF technique has been the standard, most widely used monitoring method of airborne asbestos fibres in industry.

Considerable research has been conducted on the MF technique's statistical ability, its limitations, and alternate monitoring technologies, including reports by Baron (1978), Beckett (1980), and

Chatfield (1980). The MF technique has several limitations, including its high cost and time-consuming nature, and reference must also be made to the fact that considerable doubt exists as to the validity of reporting results in the 1.0 - 0.1 f/cc range. The Ontario Research Foundation (ORF), one of the recognized leaders in fibre-counting technology, will not report results below 0.1 f/cc using this method. For further information on this subject reference should be made to other studies being undertaken for the Commission. Some relevant extracts from material in the possession of the Commission follow.

Extracts from Documents Discussing the Accuracy and Precision of Membrane Filter Counting

1. From Dr. E.J. Chatfield, "The Problems of Measurement of Asbestos," in Proceedings of The Royal Commission on Asbestos, Second Public Meeting, Friday, December 12, 1980 (Toronto: Royal Commission on Asbestos, February 1981):

   "It has been shown that, although a single labortory can achieve good reproducibility, inter-labortory analyses show greater variability. This is demonstrated by an inter-laboratory fibre counting exercise which was performed in 1978 using the NIOSH technique. The eighteen individuals involved in this study were all experienced in phase contrast fibre counting. Some of the results are shown in Table 1. It can be seen that there was a significant range in the counts reported for each filter. In one case, the ratio of the highest to the lowest count was a factor of 6.2. On this filter sample, one counter was able to find 6.2 times more fibres than another counter." [Appendix A, p. 7; See also Table 1, p. 8].

2. From G.S. Rajhans and G.M. Bragg, "A Statistical Analysis of Asbestos Fibre Counting in the Laboratory and Industrial Environment," American Industrial Hygiene Association Journal 36 (December 1975): 909-915:

   "Under field conditions the standard deviation of the results varied between 0.4-1.2 f/ml. Under ideal laboratory conditions the standard deviations of the counts were approximately 0.2 f/ml."

3. From Air Monitoring Committee of the Asbestos Information Association/North America, Harrison B. Rhodes, Chairman, "A Study of the Empirical Precision of Airborne Asbestos Concentration Measurements in the Workplace by the Membrane Filter Method" draft (Arlington, Virginia: AIA/NA, July 1, 1981):

   "Below about 0.5 fibers/cc > 5 [um], the confidence interval increases rapidly so that the results are only qualitative at best."

   "...it is not possible to statistically reliably detect work-place airborne asbestos levels in the range of 0.1 fibers per cubic centimeter."

4. From Gerald R. Chase and Harrison B. Rhodes, "Measurement of Asbestos Levels in the Workplace" (Statement submitted to the Royal Commission on Asbestos on behalf of the Asbestos Information Association/North America, Toronto, August 14, 1981):

   "In order to allow for the relatively large variability in the membrane filter method, as well as additional random variability in actual workplace asbestos concentrations, the employer must measure levels far below a mandatory standard to provide reasonable confidence that his workplace complies with the standard." [p. 3]

Throughout this study, constant reference will be made to the Ontario Ministry of Labour air surveys of industrial establishments and to fibre readings reported in the literature. Of necessity it has been assumed for the purposes of this study that all results so reported are valid. The reader is cautioned that the reliability of fibre counts below approximately 0.5 f/cc are questionable.

It is certainly self-evident that further research is indicated in the area of airborne fibre monitoring, particularly so in light of the current trend of government regulation of exposure levels to what is generally considered the limits of accurate measurement by the MF technique.

1.4 Study Methodology

The findings of this study are founded on data obtained primarily from:

(a) published literature (see Appendix A);

(b) the Ontario asbestos industry;

(c) Ontario Ministry of Labour files of plant visits containing field inspector reports, air samplings, and Ministry directives issued to concerned industries.

An attempt was made to contact, either in person or by telephone, representatives from each "category" of asbestos-handling industries. Plant visits of most of the known primary asbestos product manufacturers were undertaken, and information gained through on-site study supplemented by inspection of the Ontario Ministry of Labour files. In addition, a questionnaire was prepared and sent to a listing of asbestos-concerned industries.

2.0 LITERATURE REVIEW

An extensive literature survey resulted in the attached bibliography (Appendix A) and a considerable amount of information about the asbestos control problem, particularly in the United States.

The literature collection focuses on published information relevant to one or more of the following topics:

(a) engineering costing data;

(b) air pollution control equipment;

(c) asbestos substitutes;

(d) surveys of workplace exposure to asbestos;

(e) asbestos industry production within Canada/Ontario;

(f) asbestos-related employment in Ontario.

The resulting information provides a broad basis of background knowledge necessary for specific consideration of the asbestos industry situation in Ontario and the resulting impact of revisions to the asbestos dust standard.

In particular, four publications have proven to be most valuable and will be summarized here. They include:

(a) "Asbestos Dust Technological Feasibility Assessment and Economic Impact Analysis of the Proposed Federal Occupational Standard" (Wright _et al._ 1978);

(b) "Technological Feasibility and Economic Impact of OSHA Proposed Revision to the Asbestos Standard" (Daly _et al._ 1976);

(c) Proceedings of the National Workshop on Substitutes for Asbestos (U.S. Environmental Protection Agency 1980);

(d) "Capital and Operating Costs of Selected Air Pollution Control Systems" (Kinkley and Neveril, 1976);

Recently, we have been informed that a report entitled "Asbestos Substitute Performance Analysis" (Krusell and Cogley, 1981) has been produced. We have not been able to use this information in the preparation of our study.

2.1 Research Triangle Institute Report (Wright et al. 1978)

"Asbestos Dust Technological Feasibility Assessment and Economic Impact Analysis of the Proposed Federal Occupational Standard" (Wright et al. 1978) is a comprehensive project report prepared for the U.S. Department of Occupational Safety and Health Administration by the Research Triangle Institute (RTI) in conjunction with CONSAD Research Corporation and Clayton Environmental Consultants, Inc. The report was prepared as a consequence of the 1975 OSHA asbestos standard revision proposal which was intended to apply directly to all industries except the construction industry. However, as construction is a prime consumer of asbestos end products, the economic impact analysis detailed in this report was based on the assumption that the proposed standard applies to both general industry and construction.

The main objectives of the report were, therefore:

- To assess the technological feasibility of applying the proposed standard both to general industry and to the construction industry;
- To analyze the economic impact of the proposed standard on industries which manufacture or use asbestos-containing products;
- To analyze the economic impact of the proposed standard on the national economy; and

To investigate potential substitutes for asbestos (Wright *et al.* 1978).

To accomplish this, the authors considered "the incremental charges, cost and impact associated with lowering the current permissible exposure limit of 2.0 f/cc [8-hr. TWA (time-weighted average)] and 10 f/cc (ceiling) to alternative exposure levels called 'scenarios'...." The three scenarios considered were:

(a) 1 f/cc TWA, 5 f/cc ceiling;

(b) 0.5 f/cc TWA, 5.0 f/cc ceiling;

(c) 0.1 f/cc TWA, 0.5 f/cc ceiling.

The resulting economic conclusions are *not* specifically applicable to the Ontario situation due to the large differences in market size and product diversity. However, the individual process descriptions, required engineering controls, and achievable exposure levels are, to some degree, relevant.

In this report, consideration of construction is isolated from that of general industry at all stages. This has been done because of the preponderance of sporadic operations, small firms, and temporary worksites, which influence the report's methodology and cost assessment. Specifically, each examined process within an individual industry is analyzed, based on an assumption of compliance attainment with regard to the current enforced asbestos exposure standards (i.e., 2 f/cc TWA), and incremental costs and impacts attributable to the new requirement of each of the three scenarios.

OSHA's philosophy and that observed in cost of compliance estimations within this report is that the application of engineering controls where feasible is the method of choice, followed by work

practice controls, and finally personal protection devices. Engineering controls include, primarily, isolation, enclosure, local, and general exhaust ventilation with dust collection, and wet processing. Due to the transient nature of construction activities, these fixed engineering control methods are not directly implementable in a fashion similar to that of the general industry.

The report findings are based on data obtained through:

(a) a review of existing documents from government sources, trade journals, and industry annual reports;

(b) telephone and in-person interviews with OSHA and NIOSH officials, representatives of industry, trade associations, unions, and universities;

(c) solicitation of production and employment data from industry sources;

(d) a collection of engineering data from a representative sampling of asbestos users on the subject of current and projected methods of exposure control and work practices;

(e) on-site plant visits.

With this data in hand, the technological feasibility of each proposed provision was determined on the basis of whether the provision can be met by current technology, regardless of cost, based on consideration of:

- use of engineering controls and work practices;
- use of substitutes for asbestos;
- switch to competitive products; and
- abandoning an asbestos product line (Wright _et al._ 1978).

Costs were then determined using the method of compliance judged most

probable. The total costs incurred for engineering controls, ancillary costs (e.g., monitoring, medical surveillance, record keeping), and maintenance and energy costs were expressed on a per production worker/per shift basis and finally extrapolated to total employment figures for each particular industry segment.

For specific determination of economic impact the American asbestos industries were further broken down to a primary industry group consisting of:

. Asbestos-cement pipe;
. Asbestos-cement sheet, shingles, and siding;
*. Asbestos friction materials;
*. Vinyl-asbestos floor tile and flooring;
*. Asbestos reinforced plastics;
*. Asbestos paper products;
*. Asbestos paints, coatings, and sealants;
*. Asbestos gaskets, seals, and packing materials;
*. Asbestos textiles;

and secondary industries comprised of:

*. Automotive aftermarket (friction material refacing, friction material repackaging, and general repair);
*. Shipbuilding and ship repair; and
*. Secondary fabricators (asbestos-cement sheets, asbestos textiles, asbestos reinforced plastics, asbestos paper products, and asbestos gaskets and packing materials) (Wright _et al._ 1978).
[NOTE: *These industries are believed to be represented in Ontario (Bragg).]

Separate consideration of the construction industry was undertaken by categorization of asbestos usage as follows:

. Asbestos-cement pipe installation;
. Asbestos-cement sheet and panel installation;
. Roofing and flooring;
. Drywall removal;
. Insulation - all types; and
. Demolition (Wright _et al._ 1978).

The findings of these reports are summarized below.

Technological Feasibility

The technological feasibility of compliance and achievable fibre levels as of 1978 are discussed with respect to primary industries and are reproduced in Appendix B-1.

Secondary industries are capable of achieving on average:

. 0.2 f/cc in the rebuilding/refacing sector;

. 0.1 f/cc in the repackaging and general repair sectors of the automotive aftermarket;

. 2.0 f/cc in ship repairing;

. 0.5 f/cc in ship building, primarily through use on non-asbestos products;

. 0.1 f/cc for fabricators using reinforced plastics, paper, packings and gaskets;

. 0.5 f/cc for fabricators using textiles and asbestos-cement sheet.

Within the construction industry, average exposure levels of 0.5 f/cc are feasible with use of local exhaust ventilation and proper equipment operator training during installation of AC sheets, AC pipe, architectural panels and roofing felts. For the removal of old roofing, no adequate controls are available, and the resultant exposure level is normally below 2.0 f/cc. Similarly, it is concluded that during old dry wall removal, demolition, and maintenance activities requiring removal of asbestos insulation, exposure levels of greater than 2.0 f/cc can be expected. Reductions in above-noted exposure levels will require substitution of non-asbestos containing products and/or industry-wide use of respirators.

Economic Impact

Based on costs and implementation of the best engineering controls wherever applicable, monitoring of the work process required under the proposed standard, the medical surveillance program to be implemented in all industry segments, and supply of personal protective equipment where required, a cost of compliance was developed. Table I-1 and I-2 in Appendix B-2 show Total Capital Costs and Annualized Capital Cost of Compliance for the United States.

Extracts from the report concerned with the economic impact on prices, market structure, employment, and output levels have been placed in Appendix B.

Comments

This very large draft document covers all aspects of asbestos control in the United States. It was, however, issued in 1978 and may well be appropriate to the situation in 1977. In addition it seems to depend heavily on the document prepared by Weston for its engineering input. This document was prepared in 1976 and, hence, is now several years out of date. The report lays a heavy emphasis on the economic consequences of improved standards. By any measure these would seem to be small in terms of their effect upon the total economy of the United States. This is also borne out by Priest (1981) in a more recent study. We do not have the facilities to duplicate this type of study; however, there would seem to be little reason either to question this conclusion or to conclude that the situation would be any different in Ontario except for the possibility of industry moving to other provinces with lower control standards. In terms of

relevance to Ontario today, we feel that this study has placed too little emphasis on the move towards substitutes. The report assumes application of uniform standards of control across an industry and is not detailed by process. Furthermore, the fibre count data is reported as average figures and not maxima and minima. As a result it is rather difficult to conclude where problems would lie if restricted controls were implemented.

The report is not a final draft. Possibly because of this it contains many inconsistencies and a good deal of repeated material. We have been informed indirectly that this report is unlikely to proceed to a final draft due to the present regulatory environment in the United States.

2.2 Weston Document (Daly *et al.* 1976)

Weston Environmental Consultants' report (Daly *et al.* 1976) "Technological Feasibility and Economic Impact of OSHA Proposed Revision to the Asbestos Standard" was prepared for the Asbestos Information Association/North America by Weston in 1976. Weston, in reaction to the proposed 1975 OSHA revision to the asbestos standard (0.5 f/cc TWA), "...investigated how asbestos fibers are processed and incorporated into other products as they move through the industrial sectors..." (Daly *et al.* 1976). As the construction industry was excluded from the original proposed asbestos standard revisions, Weston considered only the general asbestos industry which they subdivided into primary, secondary, and consumer industry groups. Information was gathered through:

(a) plant visits and inspections,

(b) questionnaires,

(c) telephone interviews

to the three industry groups plus other sources including trade associations, government agencies, and educational institutions.

Analysis proceeded through the following development for the primary and secondary groups:

(a) process description,

(b) work practices/controls,

(c) existing fibre counts,

(d) best available technology (BAT),

(e) projected fibre counts,

(f) advanced technology

and was based largely on the industry response to a fairly comprehensive survey/questionnaire distributed by Weston. Separate consideration of their findings will be given to each of the three industry groups.

Primary Industries

The primary group, defined as those industries which start the manufacturing process with raw asbestos fibre producing an intermediate or finished product, was broken down by type of product as follows:

. Asbestos Paper;
. Asbestos Cement Pipe;
. Floor Tile;
. Friction Products;
. Paints, Coatings, and Sealants;
. Asbestos Cement Sheet;
. Gaskets and Packings;

- Asbestos-Reinforced Plastics;
- Asbestos Textiles;
- Miscellaneous (Daly et al. 1976).

Appendix C-1 outlines fibre usage and percent survey coverage of each of the ten primary industry segments. Technological conclusions specific to the ten primary industry segments were developed based on current control technology and associated fibre levels, a definition of BAT and achievable fibre levels with BAT.

Recurrent amongst all ten primary industry groups using BAT were the following elements:

(a) Adequate ventilation and exhaust velocities;

(b) Proper bag handling;

(c) Well-designed hoods;

(d) Proper bag disposal;

(e) Pulpable bags where practicable;

(f) Isolation/enclosure technology;

(g) Central vacuum systems.

Further, advanced technology was described for each segment and characteristically involved:

(a) Advanced raw fibre packaging and shipment techniques such as pelletized fibre, bulk loads, and standardization of bag size;

(b) Automatic bag opening devices;

(c) Wet dust suppression.

The conclusions developed for the primary industries by Weston are included in Appendix C-2. Capital charges, annual compliance costs and resultant percentage increase in selling price by primary

industry segment are tabulated in Appendix C-3.

Major conclusions outlined are:

(a) Average primary industry increase in selling price is 5.1%.

(b) The 10 primary industry segments have been/are moving "...expeditiously to reduce worker exposure to airborne asbestos" (Daly et al. 1976).

(c) Fibre count readings are subject to considerable variation; test method and employee work practice appear to be sources of variation. The latter has an important impact on dust generation and exposure levels.

(d) Two major areas of dust generation are fibre introduction into the process and finishing.

(e) Implementation of BAT is projected to achieve 0.5 f/cc TWA at only 35% of the identified work stations. All work stations are expected to achieve 2 f/cc TWA or less.

(f) "Implementation of BAT...will require 3 to 5 years based on industry estimates and the implementation of the compliance schedules required by the existing standard" (Daly et al. 1976).

(g) Implementation of BAT in the primary group is estimated to cost approximately $1770.00/employee/year.

Secondary Industries

Secondary industries are defined as "those [industries] which continue the manufacturing process by receiving a material which contains asbestos (already modified by the primary industries) and

further process, modify or fabricate this product to produce another intermediate or final product." This group is described as "highly diversified...[both] in number of plants involved and variety of final or intermediate products manufactured" (Daly et al. 1976).

Although control equipment and work practices employed in the primary and secondary groups are similar, the secondary industry is characterized by a prevalence of hand-operated power tools, and machining operations; therefore, implementation of BAT will be more difficult due to the variety of processes, machining, products and technologies present. Within the secondary industries labour-intensive operations and custom fabrication occur in higher proportions than in the primary group. Many plants indicated that with the implementation of the proposed standard, certain operations would be discontinued. Typically, these were involved with finishing processes such as grinding, sawing, and sanding, all of which produce significant quantities of asbestos-laiden dust. The decision to discontinue these operations would be related to the proportion of plant operations involved with asbestos.

Estimated capital charges and annual cost to achieve BAT within the secondary industry segment are presented in Appendix C-4. Overall, eighty-five percent of the cost of compliance for secondary industries is made up of industrial hygiene and medical program costs versus fifty-one percent for the primary segment. Specific conclusions reached by Weston for the secondary industry group are:

(a) The 5.0 f/cc TWA exposure standard is currently being met by the majority of secondary industries.

(b) Implementation of BAT in the secondary industries is estimated to cost $995/employee annually.

(c) Expected average product price increase exclusive of raw material price increases passed through by the primary group is 4.7%.

(d) Eighty-five percent (85%) of the compliance costs are estimated to occur within the brake service/repair sector.

Consumer Industries

Those industries which "...purchase a finished asbestos-containing product...and apply, install, erect or consume...without further [physical] modification of the product...."(Daly *et al.* 1976) are designated as consumer industries. Weston determined that while some employee exposure may be experienced in the consumer industries, it is below the levels described in the proposed standard. This is based on the unlikelihood of asbestos fibre disassociating itself from asbestos-containing material in sufficient quantities to exceed an eight-hour TWA or ceiling limit.

Therefore, Weston concluded that:

(a) All consumer industries are assumed to be currently meeting the proposed standard.

(b) BAT is not applicable.

(c) The only costs incurred are for industrial hygiene and medical programs, estimated to cost annually $140/employee. This is based on costs for medical surveillance of those employees in the consumer industries (11,800,000 persons) who

could reasonably be assured to handle asbestos-containing products.

(d) The direct effects of price increases from the primary and secondary industry groups will be negligible in almost all industrial product groups as asbestos material prices are a minor constituent of most product prices.

(e) Product cost increases, expected to result from the implementation of the proposed standard, are expected to cause a decline within the textile/yarn sector and reduce exports of friction materials without stimulating imports.

(f) For the consumer industries, a 0.3% product price increase is expected, exclusive of the primary and secondary price increases.

Final Summary

Costs of compliance per employee per year for the secondary group were estimated as $995.00. The similar figure for the primary group is $1,770.00 per employee per year, and for the consumer group $140/employee/year.

Substitutes were not considered in depth in this report except in the friction products sector where it was concluded that "No substitute has been proven for the asbestos in the friction product nor can the country do without it...." (Daly et al. 1976). Implementation of BAT will achieve 2.0 f/cc in all areas of the primary and secondary industries, but 0.5 f/cc is not achievable at all work stations in either industry.

An economic impact summary is presented in Appendix C-5.

Comments

Weston undertook the same type of study as this present work; however, based upon our findings to be reported later in this study, we feel that some of the material in the Weston report is outdated. A number of industries in Ontario which are working at fibre levels around 2 f/cc are using the technology which is described in the Weston report; that is, local exhaust ventilation, well-designed hoods, wet dust suppression, and reasonable housekeeping practices. Since 1976, however, some industries have moved to enclosures and semi-enclosed work stations. In these locations there has usually been a considerable improvement in measured dust levels from that of the processes outlined by Weston. The situation with respect to cost will be dealt with in Section 4 of this study. Again, this report documents average fibre levels.

2.3 Workshop on Asbestos Substitutes

The National Workshop on Substitutes for Asbestos (U.S. Environmental Protection Agency 1980) was co-sponsored by the U.S. Environmental Protection Agency, U.S. Consumer Product Safety Commission, and the Inter-agency Regulatory Liaison Group. The intent was to "...obtain more information on the technical and economic feasibility and possible health problems of substitutes for asbestos, for use in considering regulation of asbestos" (U.S. Environmental Protection Agency 1980).

The two areas of development were first, economic sessions considering the technical and economic feasibility of substitution by asbestos product category and second, health sessions focusing on the

toxicity of asbestos substitutes. Examination of the economic workshop discussions will be presented by product category for the areas most relevant to Ontario industry.

Friction Materials

In a presentation by the Bendix Corporation, it was stated that:

> Non-asbestos organic disc pads are still in the development stage because several problems have not yet been resolved:
>
> - rotor compatibility;
> - wear durability;
> - noise properties;
> - processing (Bendix March 1981).

The first generation of non-organic drum brake linings is being currently evaluated by some vehicle manufacturers. Direct substitution of alternate fibres in existing asbestos formulations were not successful. Radically different approaches to material formulations and processing technology are necessary and require substantial capital investment.

Semi-metallic asbestos-free friction materials originally developed for heavy duty applications are currently experiencing increased usage.

Overall, engineering development of the above-mentioned materials and other proprietary alternatives continues. Bendix is committed to offering in the early 1980's a long-wearing, high performance, asbestos-free friction material.

Gaskets and Packings

A submission by Greene, Tweed and Co. stated:

ALTERNATIVES TO ASBESTOS AS A BRAIDED PACKING MATERIAL

> The advantages of asbestos packings are that they are strong, inexpensive, and are resistant to heat and chemicals. Disadvantages are that they are very abrasive and have poor heat dissipation. Substitutes for asbestos packings are available. To properly evaluate their performance, mechanical (pressure, velocity), chemical (acidity, causticity), and thermal (environmental, friction) factors must be compared to those of asbestos packings. The costs of non-asbestos packings might seem higher than those of asbestos packings; however, when maintenance and operating costs are considered, the newer synthetic packings are competitive (Environmental Protection Agency, 1980).

These include PTFE (polytetrafluoroethylene, or Teflon) which can be used in virtually all fluids to 500°F. Commonly PTFE is loaded with glass or carbon fibres to reduce creep relaxation. Above 500°F, graphite sheet metal gaskets are a prime asbestos replacement but currently are not cost viable.

Asbestos in Plastics and Floor Tile

Asbestos has long been considered a technically and economically justified reinforcer/filler for plastics. However, due to government health regulations and the negative publicity associated with asbestos, use has been discouraged in all but a few applications. Traditionally, two areas of asbestos usage in plastics have been dominant. These are phenolic moulding compounds and vinyl asbestos floor tile (VAT).

Over the past eight years usage of asbestos in phenolics has been all but eliminated* while in VAT the move away appears to have just

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[*Note: This is not so in Canada (Bragg).]

started. Mica, clay, clay talc, and Wollastonite are proven to be cost-effective naturally-occurring mineral asbestos replacements for the phenolics industry. In VAT, competition from synthetic carpeting materials as well as non-asbestos containing types of floor tiles are reducing asbestos consumption. Several industry sources are quoted as aiming for a phase-out of asbestos in VAT in the next two years, primarily due to the "bad" name asbestos has acquired.

Asbestos Roofing Felt

According to a brief presented at the Workshop by Koppers Co., Inc. and GCA Corp., adequate alternatives to asbestos-containing roofing felt now exist. They include organic and fibreglass felts. Consideration of strength and durability, product life, and cost have led industry representatives to different opinions on an overall product superiority as the fibreglass and asbestos felts have been in use for less than twenty years in the U.S. Only organic felts have a significant history of in-industry use. As familiarity in application and manufacture grow in conjunction with a narrowing price differential, it is expected that substitutes will become widely available; indeed fibreglass is currently gaining general acceptance. Current price estimates for installed roofing, material and labour included, are:

FELT TYPE	COST/SQUARE INSTALLED
Organic felt	\$50-\$60
Asbestos felt	70.00
Fibreglass felt	70.00

Sealants and Cements

Substitutes are available in this field; however, they are more expensive and often have less ability to absorb oil. Their resistance to sagging and settling is not as good as asbestos.

The Workshop Proceedings are highly recommended for the discussions which are reprinted there. These discussions highlight the problems encountered in moving to substitutes. In particular, the necessity to test substitutes over a period of time in actual applications is emphasized as well as the period of time necessary to move a substitute into the full market area.

2.4 Capital and Operating Costs of Selected Air Pollution Control Equipment

Sponsored by the United States Environmental Protection Agency, Capital and Operating Costs of Selected Air Pollution Control Equipment (Neveril 1978) was designed as a manual to assist American regulatory agencies responsible for controlling air pollution and for investigating the cost of control systems for various manufacturers' processes. Individual component costs are identified so that a realistic cost estimate may be determined for any specific application.

In the manual, cost estimating procedures and cost curves for eight control devices are included, three of which--electrostatic precipitators, wet scrubbers, and fabric filters--are commonly used within the asbestos-using industries. In addition to capital costs for control devices, methods for estimating operating and maintenance

costs are provided, allowing determination of an annualized cost.

The manual presents, on a component basis, data for equipment costs reference dated to December 1977 and are estimated to be accurate to ±20%. Methods for cost extrapolation to future dates as well as conversion to Canadian dollars are generally available reference items.

An example of a work station costing is provided in the Costing Procedures section of this progress report, and methods used in its preparation which originated in this cost estimation manual are referenced there.

Another generally useful reference, Industrial Gas Cleaning (Strauss 1975), provides detailed performance and design technology information for the earlier mentioned dust collection systems commonly encountered in asbestos using industries. In addition, Strauss provides a section on the economics of industrial gas cleaning. Strauss gives cost curves for equipment capital expenditures, charts of typical charges incurred for design and project management, a section on operating and maintenance costs, and finally, an outline on comparing cost-effectiveness of alternative control designs.

Engineering Aspects of Asbestos Dust Control (Rajhans and Bragg 1975) is a useful introduction to asbestos, the asbestos industry, and the most commonly used current control technologies. Included are considerations of mineralogy, chemical/physical properties, worldwide production, monitoring and toxicology, as well as chapters focusing on engineering controls and the economics of dust control.

Other publications having specific, current information on engineering control of asbestos dust include those by Bastress *et al.* (1974), Curtis and Bierbaum (1975), Gagan (1980), Goldfield (1974), Hagopian (1976), McDermott (1977), and Vandegrift (1973), among others.

In the subject area of fibre levels and workplace exposure, useful information was found in references including Fontaine and Trayer (1975), Hammad *et al.* (1979), Kim *et al.* (1980), Murphy *et al.* (1971), Reitze *et al.* (1972), and Rohl *et al.* (1976).

3.0 DISCUSSION OF CONTROL METHODS

3.1 Methods of Control

The methods available for control of environmental hazards may be grouped in a number of ways. We may consider grouping the controls by location as:

(a) source,

(b) air path,

(c) the receiver.

This list indicates the locations where control is attempted. Control at the source is best and includes such methods as replacing the toxic contaminant or totally enclosing it. Control of the air path, using methods such as exhaust ventilation and monitoring, assumes that the immediate environment of the process or material has been contaminated and that this immediate environment is to be restricted or monitored in some way. Control at the receiver, including personal protective devices and rotation of workers, is a method of exercising control late in the process. It is generally considered to be the least satisfactory alternative.

Another method of arranging the possible alternatives for control is through the following hierarchy:

Specific:

(a) substitution,

(b) alteration of process,

(c) isolation or enclosure,

(d) wet methods,

(e) local exhaust,

(f) dilution ventilation;

General:

(g) personal protective devices,

(h) housekeeping,

(i) monitoring, alarms, medical programs,

(j) training.

The specific groups are generally considered to be of decreasing effectiveness from top to bottom and usually of decreasing cost. They must usually be applied to each specific manufacturing or processing part of a factory. The general methods can be applied in addition to the specific ones and may be either particular to a process or may be used throughout a plant. We will discuss each of these ten procedures and their general effectiveness with respect to asbestos. The costs and levels of dust control which are achievable will be discussed later.

Substitution

The most satisfactory method of dealing with a toxic material is to eliminate its use entirely. In the case of asbestos this procedure is well advanced in many fields. There is, to our knowledge, no new use of asbestos fireproofing in buildings or in ship repair. Asbestos-free floor tile is now available in the United States and a number of small users in Ontario have indicated to us that they have stopped asbestos use entirely. This is particularly true of insulation installers. The move to replacement is occurring in the manufacture of floor tile, gaskets, automotive disc pads, drum brake

linings, plastics, and filtration media. The rate of replacement varies for different fields and depends upon the economics, customer acceptance, and industry process abilities.

The following information (courtesy of Mr. Jim To of Ontario Hydro) indicates the way in which a large organization completed an organized, comprehensive asbestos substitution and elimination program. The decision to eliminate most asbestos was made at the beginning of a large Ontario Hydro building program in approximately 1968. A further decision in the period 1969-1970 was to eliminate crocidolite entirely, to install no new insulation products containing asbestos and to replace all asbestos insulation with non-asbestos insulation as normal overhauls were undertaken. This process is not yet finished. As a result Ontario Hydro still accepts asbestos-containing material such as gaskets and floor tiles. In the earlier period of the program two committees were formed, one to consider work procedures to minimize dust and the other to look for asbestos-free insulation materials. The latter activity was not immediately successful, but by 1972 all insulating materials used contained no asbestos. Ontario Hydro has produced a "qualified product list" which provides Hydro-approved non-asbestos insulating materials. In the original period of replacement the non-asbestos insulators were a little more expensive, but this is no longer true. Older plants containing asbestos insulation were not disturbed but were wrapped with cloth and aluminum sheeting. Through the normal attrition of equipment and maintenance procedures the asbestos in these plants is gradually being replaced.

In addition Ontario Hydro has a sophisticated procedure for asbestos removal activities.

Alteration of Process

The general principle of process substitution is that as processes tend to become more continuous they become less hazardous. For example, knife-cutting of asbestos sheet tends to create considerably less dust than sawing. Outside of asbestos mills, those processes which tend to create the most asbestos dust are weaving, grinding, sawing, and debagging. Manufacturing processes have been developed in some cases where these operations have been replaced with alternatives.

Isolation and Enclosure

Isolation is the term applied when some form of barrier is placed between the hazard and those who might be affected. The normal barrier is a physical one but distance and time may also provide isolation. Examples of isolation used in the asbestos industry are the use of plastic bags in modern packaging processes in place of the older, dusty paper bags. A number of machining operations can be enclosed. This depends on the necessity for the operator to see and have contact with the actual operation. As in the case of process alteration, continuous processes tend to be more amenable to enclosure and isolation than are discontinuous hand processes. The modern asbestos mill is almost completely isolated and the product is seldom seen in the mill building. A fundamental aspect of enclosure use is that all parts of the enclosure should be at lower pressure than the associated

workers' area. For airtight or near-airtight enclosures this may be done with a very small amount of air but very small local failures to achieve this negative pressure may create quite dusty conditions.

There is a considerable amount of activity in Ontario devoted to enclosing processes which use asbestos. Some of the most fibre-free environments are created in Ontario industry using effective enclosure techniques.

Process isolation can, however, produce some extreme hazards. When enclosures must be opened for maintenance or operational adjustments, an extremely low fibre level can immediately rise to an exceptionally high level. Under these circumstances it is the worker who must be isolated rather than the process.

In asbestos mills and mines the operator of the process is occasionally enclosed in a booth or operating room.

Wet Methods

A common procedure for asbestos working is wet processing. With asbestos-containing sheet and pipe the sawing process may be undertaken under water or under a water spray. This can enormously reduce the dust level at the sawing station but can create dust problems from dried powder arising from water left lying to dry as well as the associated asbestos contamination of the water.

Local Exhaust

Exhausting contaminated air from a region as close as possible to the process has been the traditional way of dealing with asbestos dust problems. The basic principles of this equipment have been well

understood for some time. The Handbook of the American Conference of Governmental Industrial Hygienists entitled Industrial Ventilation (16th edition, 1980) contains extensive engineering information on the design of local exhaust ventilation systems. Recommended sizes, shapes, air flow rates, and achievable fibre standards are all documented in this volume. It has also been traditionally observed that this provision of local ventilation requires considerable expertise in its application. The problem lies in the fundamental fact of fluid mechanics that blowing of air is a considerably more efficiently directed process than is air suction. A jet of air from a pipe will decrease to approximately 10% of its exit velocity at 30 exit diameters downstream. When sucking or exhausting air the suction velocity drops to about 10% of the pipe velocity at less than 1 diameter away from the exhaust opening. As a result the exhaust hood must carefully and narrowly enclose the dust-creating process and the velocities in the ducting must be very high. Hence, this process tends to both obstruct production and also to be very expensive. The exhausted air must be made up by incoming air to the plant. In the Canadian environment provision of warm air in these large quantities can itself be an exceptionally expensive procedure. It has been observed that while the very best and most efficient local exhaust systems may achieve fibre levels as low as 0.1 to 1 f/cc, a large number of these systems spread over a plant will achieve fibre levels only around 1.0-2.0 f/cc for the plant. Whenever large capital expenditures are made for asbestos dust control, the great majority of the cost is usually attributable to the provision of conditioned air

and the exhausting of contaminated air in local exhaust systems.

Dilution Ventilation

Dilution ventilation is the process of mixing contaminated air with uncontaminated air in such a way as to bring the concentration of contaminant low enough to be within tolerable limits. The modern standards required for asbestos control are sufficiently stringent that this method can seldom be used. It is, however, useful as an additional technique in conjunction with local exhaust ventilation and in places where the level of contamination is already low.

Personal Protective Devices

Personal protective devices may, of course, be utilized in addition to any or all of the above methods. For asbestos the basic personal protective device is some form of respirator. These come in various forms, the simplest and cheapest of which is a semi-rigid cup-like filtration paper on an elastic band. A larger, heavier, and more efficient respirator which is more easily fitted to the face and, therefore, gives a better seal is the cartridge type. The better respirator-face seal of this device makes it more appropriate to use at higher fibre densities. This respirator, however, is particularly heavy and inappropriate for permanent wear. Air filtering helmets are available which filter the air through a motor fan combination and provide a wash of cleaned air over the head and down behind a transparent face mask which is worn permanently with the safety helmet. These have been used in some locations in Ontario industry. They would seem to be suitable for some of the lower fibre levels but

some wearers complain of headaches. An air-supplied respirator has a separate air supply either carried on the back in a compressed air bottle or supplied by hose from a permanent air supply situation. These are the safest respirators for very high concentrations of dust but are inappropriate for permanent wear. Coveralls, which can be either disposable or permanent and regularly laundered, are also useful. Some typical costs for personal protective devices are given in Appendix E as are the recommendations of the Ontario Ministry of Labour concerning the use of each type.

Housekeeping

Housekeeping is the term encompassing all cleaning practices which make control methods more effective. The methods are usually mundane and include such recommendations as vacuuming rather than sweeping of dust, closing all asbestos containers when not in use, regular vacuuming of floors, walls, and ceilings, effective maintenance of air cleaning devices, regular replacement of respirators, vacuuming of manufactured parts, and many other similar items. It is well known in the industrial hygiene field that the effectiveness of general housekeeping procedures is often underrated. It is not unusual to see fibre levels decreased by one-half to one-quarter by the implementation of effective housekeeping practices. It is also generally understood that poor housekeeping practices such as dust spills on the outside of enclosures can render enclosures and hoods ineffective. The situation with respect to housekeeping in industrial hygiene could be considered similar to the effect of cleanliness in reducing germ-based diseases in the public health field.

Monitoring Alarms and Medical Programs

These procedures monitor rather than solve the contamination problem. For many toxic substances monitoring, provision of alarms, and provision of an associated medical monitoring program is a straightforward process. In the case of asbestos the normal procedure of monitoring and alarms is not possible. In the vast majority of engineered process installations dealing with toxic materials, a continuous watch can be kept and alarms sounded if dangerous conditions arise. Since a suitable, effective, and economic monitor does not exist for asbestos, this whole procedure is not available. As a result there are no engineering solutions to provide constant control over, and monitoring of, the working environment for asbestos. This single lack is by far the greatest engineering constraint to providing a more effective engineering solution to the asbestos dust problem. Any attempt to control at, say, the 0.5 f/cc level will require dependable measurement well below this level.

In addition the operation of many engineering controls, such as ventilation hoods, is poorly understood because their effectiveness cannot be constantly monitored.

Training

Another general procedure available to all aspects of asbestos handling is that the users of asbestos can be trained in its safe use. The use of proper housecleaning, effective use and fitting of respirators, and safe work practices in the presence of asbestos all need to be provided for new workers in the field. This is a

particular problem with work forces which are highly transient. In some cases in Ontario there is also a language problem. Some employers in Ontario provide regular weekly safety sessions where this type of training is undertaken. Typically this is one-half to one hour per week.

Historically, the methods of control applied in asbestos have been moving up the list of specific control methods, that is, from dilution ventilation in the past towards substitution in the future and making increased use of all aspects of the general control items. At the present time the largest amount of activity in Ontario industry is on local exhaust, enclosure, and substitution. The greatest problem at present in the case of asbestos is that of effective monitoring so that increased effectiveness can be monitored.

The examples quoted in this section have been essentially industrial in orientation. The same principles, however, apply in the case of construction. For example, the cutting of asbestos cement pipe has traditionally been done with saws. Alteration of this process to cutting by a procedure similar to that by which copper pipe is cut has succeeded in decreasing fibre levels in the cases where it has been applied. This procedure is not in general use at the moment on construction sites in Ontario. In the case of construction where asbestos sheet is cut by saw, local exhaust systems attached to the saw are available in the United States. This will lower fibre levels, but typically is not in use in Ontario. Personal protective devices are used among knowledgeable construction workers using asbestos sheet and are as effective as they are in the industrial situation.

3.2 Effectiveness of Control

The effectiveness of control depends upon the tendency of any process to generate dust. A summary of the dust levels to be expected is given in Table 3.1 for construction activities (Her Majesty's Stationery Office) and for typical workplaces in Table 3.2 (Wright et al. 1978). Some possible fibre levels for typical processes found in Ontario are given in Table 3.3.

A careful and detailed measure of the effectiveness in terms of fibre levels of the various control methods is difficult to obtain. The basic procedure used in this report has been to observe the control methods in use at present in industry and to relate these to the fibre levels obtained by the Ontario Ministry of Labour in those locations. This procedure has a number of problems. It would, however, seem to be the best available procedure at this time.

The optical fibre counting technique used is known to have problems inherent in its application. The variability of fibre counts and the inability of the fibre counts to determine very low concentrations and detailed dust compositions are well known and are the subject of other reports. The technique's application in a manufacturing plant, however, adds additional problems. The first of these is the frequency with which the tests are made. Ontario Ministry of Labour surveys are typically carried out every 6 months, and most companies do their own sampling as well, particularly in problem areas.

Table 3.1 - Exposure Levels in Construction

Use of asbestos/cement sheet and pipes	fibres/ml [1]	fibres/ml [2]
(1) Machine drilling	2	1.65
(2) Hand sawing	2-4	0.11
(3) Machine sawing without effective local exhaust ventilation (a) jig saw	2-10	
(b) circular saw	10-20	20
(4) Machine sawing with effective exhaust ventilation	2	
(5) Compression shearing of pipe	--	0.2

Use of asbestos insulation board		fibres/ml [3]
(1) Drilling vertical structures e.g., column casing	2-5	
(2) Drilling overhead e.g., suspended ceilings	4-10	3.3 --no control 0.1 --with shroud
(3) Sanding and surforming	6-20	
(4) Scribing and breaking	1-5	0.8
(5) Hand sawing	5-12	0.1 --no collection (but dust on floor possible cleanup problem
(6) Machine sawing without effective local exhaust ventilation (a) jig saw	5-20	2.1
(b) circular saw	20 upwards	3.0 --with control
(7) Unloading deliveries of board (short term sampling)		
(a) cut pieces	5-15	
(b) manufacturers standard size sheets	1-5	

NOTES:

1. Her Majesty's Stationery Office, Precautions in the Use of Asbestos [in the] Construction Industry, Technical Data Note 42. Source for first column.
2. Peak exposures as extracted from "Recommended standard for occupational asbestos exposure in construction and other non-fixed work operations." Asbestos Information Association/NA and Association of Asbestos Cement Pipe Producers. Source for A/C sheet and pipe.
3. Johns-Manville Research and Development Centre Report No. E411-1050-S1 and -S2. Source for insulation board.

Table 3.2 - [Typical Exposures] to Asbestos in the Workplace (Wright et al. 1978)

Category of Exposure	Estimated Uncontrolled Exposure Level (f/cc)
Asbestos Cement Pipe Installation	>25 (ceiling)
Asbestos Cement Sheet Installation	2 to >25 (ceiling)
Architectural Panel Installation	2 to >25 (ceiling)
Roofing Installation	0.1 - 0.2 (8-hr TWA)
Drywall Removal	15 (8-hr TWA)
Roof Alteration	0.0 - 1.7 (8-hr TWA)
Electric Generating Plant Maintenance	<0.1 - 5.9 (8-hr TWA)
Non-Electrical Insulation Maintenance	5.9 (8-hr TWA)
Demolition	>80 (ceiling)
Asbestos Cement Pipe Manufacturing	<0.1 - 4.8 (8-hr TWA)
Asbestos Cement Sheet Manufacturing	<0.1 - 8.4 (8-hr TWA)
Asbestos Friction Materials Manufacturing	<0.1 - 8.0 (8-hr TWA)
Vinyl Asbestos Floor Tile Manufacturing	<0.1 - 4.3 (8-hr TWA)
Asbestos Paper Products Manufacturing	<0.1 - 2.8 (8-hr TWA)
Packing and Gasket Manufacturing	<0.1 - 2.5 (8-hr TWA)
Paint, Coating, and Sealant Manufacturing	<0.1 - 8.0 (8-hr TWA)
Conventional Processing of Asbestos Textiles	0.2 - 10.0 (8-hr TWA)
Automotive Aftermarket	0.1 - 4.7 (8-hr TWA) Peaks up to 29.0
Secondary Fabrication of Asbestos Products	0.1 - 6.0 (8-hr TWA)
Shipbuilding and Repair	Peaks up to 100

Table 3.3 - Typical Ontario Processes and Fibre Levels

(Based on 1980 and 1981 Ontario Ministry of Labour reports.)

Operations typical to Ontario asbestos industry	Typical fibre levels found
Debagging	0.5 - 8.0
Pressing or Forming	0.5 - 3.0
Grinding	0.5 - 5.0
Drilling	0.5 - 2.0
Cutting - Press	0.1 - 0.7
- Hand	0.2 - 2.0
Braiding	0.1 - 3.0
Spinning Twisting	0.1 - 3.0
Sheeter Operation	0.4 - 2.0

However, fibre levels can vary by factors of 10 or more within a few seconds. Other monitoring methods have similar problems. Again, data below 0.5 f/cc is questionable.

The traditional concept of threshold limit value (TLV) is of a time-weighted average concentration for a normal eight-hour work day or forty-hour work week. The intention is to provide a value to which nearly all workers may be repeatedly exposed, day after day, without adverse effect. Measurement of this quantity requires a true average over a day. Except through the use of personal monitors, which is not a common process at the present time, this value is simply not available. Instead a sample is often taken over a fifteen-minute period.

An additional problem in the case of plant monitoring is that local problem areas do not necessarily stay localized. A single dusty location in a plant can alter the background fibre level throughout the plant or raise it at other locations which are "downstream." This effect, coupled with infrequent observation, tends to make conclusions about localized control processes difficult.

In spite of these obvious problems and the difficulties associated with drawing detailed conclusions using data of this nature, we have been able to determine a number of consistent trends within the industrial environment. We will summarize these and then give some detailed examples of their application.

(a) There is an extremely wide variability in control practices. This is true for all industries surveyed and for all sizes of industry. This variability is directly dependent on the

level of engineering expertise within any particular company. The detailed application of engineering controls requires an intimate knowledge of ventilation practices, plant processes, and air pollution technology. We would estimate that there are fewer than twenty-five people within the province who could be considered truly expert in this field, most of whom are employed in specific plants. The others work in government or as consultants. In addition, the person must have an intimate knowledge of each plant to which he intends to apply controls. As may be suspected, the larger the plant, the higher the probability that this expertise exists within the company. The result of this process is that some companies have achieved higher control capability with less money and less interference with processes than others. In addition, we have found small manufacturing facilities with no engineering skills and little knowledge of control processes who are spending money but achieving very poor control. We see this latter problem with smaller industries as an important aspect in achieving good province-wide controls.

(b) Any given fibre level cannot be achieved all the time. The situation may be considered analogous to car accidents where safe driving and safe practices cannot entirely eliminate accidents. As a result, consistently achieved fibre levels, by which we mean fibre levels which can be achieved over

ninety percent of the time, can be expected to occasionally produce very high fibre levels. An obvious example of this is the maintenance period required on all machinery. Other problems would consist of catastrophic failure of machinery, failure of air-conveying systems, worker sabotage of cleaning systems, improper usage of equipment, and high winds affecting the air cleaning system.

(c) We have also concluded that higher levels of control are not always more expensive. A considerable degree of innovative design is possible in this field. For example, some enclosures, by virtue of their efficient sealing, use very little ventilating air. Where this is possible the added expense of enclosure and reduced productivity can, to some extent, be balanced off against a considerably decreased use of ventilating air.

It is not possible to specify particular levels of expenditure or types of equipment which will produce a guaranteed level of fibre dust at all times. The points listed above outline the reasons for this. A significant proportion of industrial environments, however, may be controlled to a range between 1 and 2 f/cc by effective local exhaust procedures. Levels higher than 2 using good local exhaust often occur if poor housekeeping practices are prevalent. Levels below 1 f/cc are occasionally possible but there are many processes where levels this low cannot be achieved by local exhaust ventilation. Consistent levels of 1 f/cc using local exhaust ventilation would be extremely

difficult for such processes as debagging, grinding, and sawing.

Levels of fibre exposure around 0.5 f/cc are not and, in our estimation, cannot generally be met by open local exhaust ventilation hoods. For this level of control enclosures are required for many processes. It is our estimation that consistent fibre levels of 0.5 will need enclosure of approximately 90% of the individual industrial processes presently operating in the province.

Achievement of regular fibre exposure levels of 0.1 f/cc would require total enclosure with local exhaust ventilation from the enclosures of all asbestos machining processes. In addition some processes to which controls are not presently applied would need to be implemented. Two examples of this latter situation are packaging of such items as gaskets and brake shoes or cutting of gaskets. At the present time testing indicates that these processes all produce fibre levels below 1 f/cc with no controls. Fibre level exposures at 0.1 f/cc can only be achieved in plants with very careful housecleaning practices and cannot be achieved with the combination of enclosures and housekeeping for such problems as maintenance, equipment failure, and accidents.

It should be pointed out that many of the processes which we observed in industry that produced very low fibre levels--around 0.2 to 0.1 f/cc--were achieved by companies attempting to meet the present fibre standards or in some cases having processes which are only generating low fibre levels. We conclude from this that these large gains in collection efficiency are typical of the best available design processes at this time. The extensive use of enclosures

results in this large drop in exposure, and where enclosures are usable and properly designed they produce a very efficient collection process. Cleaning the enclosures and maintaining equipment can, however, produce high exposures.

It should be pointed out that beryllium is an extremely toxic element which is used in a number of industries including the nuclear reactor industry, and the processing of this material has been carried out for some years using nearly total enclosure. Many of the enclosure devices which we were able to observe bore considerable similarity to those devices which are used in beryllium processing although the properties and hazards of beryllium are quite different.

An important factor determining control strategy at the present time concerns the fact that air which has been contaminated with asbestos must be removed from the plant and cleaned before release to the atmosphere. At the present time the best cleaning device is a fabric filter, commonly called a baghouse; and in our estimation this also represents best possible practice. Other devices such as electrostatic precipitators and scrubbers have been tried in asbestos-cleaning applications but have so far proved unsuitable. The air which has been removed must be replaced by conditioned air. The costs of this energy for heating in the Canadian environment, particularly in winter, can be extremely large. This effect has been taken into our costing estimates in Section 4. An obvious possible solution to the loss of energy through the fabric filter is to recirculate the air from the baghouse. This is commonly done in asbestos mills and has occasionally been attempted in Ontario industry. We are not aware of

installations using a single bag filter and immediate return of the air which are capable of providing fibre levels consistently below 2 f/cc. This would seem to be due to the fact that fabric filter is not a perfect asbestos cleaner, the fact that new bags do not filter as efficiently as bags which have been "broken in," and the fact that bags wear through. A number of manufacturers in the province are, however, considering use of recirculated air. At the present time we feel that a single stage of filtration would not produce fibre levels at the 0.5 and 0.1 f/cc level in heavy dust applications. We have been informed that one manufacturer is considering a second stage of air cleaning. It is our expectation that if air is to be recirculated for energy conservation purposes, a second stage of fabric filtration or similar device will be required. This may alter the economics of recirculating the air. A possible solution to this problem which has not yet been attempted is to employ a heat exchanger to use the outgoing air to heat the incoming air with no interconnection between the two. This type of device is commonly used in power plants and the technology is not new. The expense, however, may militate against the use of such a device.

There are many exceptions to the general comments concerning fibre levels made in the above paragraphs. An example is the sawing of large 4' x 8' sheets containing asbestos. This process requires an enclosure which could be as large as 32' x 32' and then would certainly require an operator to work inside the enclosure. Another example is the debagging process. Asbestos is packaged in hard-packed plastic bags which must be opened in order to place the

asbestos into the various processes. This process has traditionally been among the dustiest in any plant. A number of automatic debagging devices are commercially available. They are, however, extremely expensive even for large plants. We also have some indication that the majority of these units are undependable and inefficient. We have not seen in Ontario a debagging process which we feel can permanently keep fibre levels in the working area at or below 0.5 f/cc. Debaggers have been discussed with a number of engineers and the universal opinion is that even the best systems available are neither effective nor reliable. Few, if any, are in continuous use.

Another problem concerns the use of compressed air. Automated machinery such as drills are commonly driven by compressed air (pneumatic systems). It is inherent in the use of a pneumatic system that the compressed air exhausts in the region of the equipment. This tends to produce a short, sharp jet of compressed air which is liable to raise large quantities of dust. Some, but not all, Ontario manufacturers have eliminated compressed air-driven machinery from these applications. Hydraulic machinery used in the same application would not appear to be significantly more expensive; however, certain of the process equipment is not made in hydraulic format. Since asbestos processing is an extremely small part of any machinery market, it is unlikely that this equipment will ever be produced specifically for asbestos use.

Another problem situation is warehousing. Currently all asbestos warehousing is kept at low fibre levels by dilution ventilation. This would seem to be effective except in cases where poor housekeeping is

present. We find that there has been very little fibre level testing in warehouses; also, we are not clear on how best to handle bag breakage in warehouses except by personal protective devices.

The construction industry is again unique in its treatment of asbestos problems. Some measurements have been taken in the United States showing the levels of exposure for construction workers. These are shown in Table 3.1. To our knowledge no regular program of equipment ventilation has been used in Ontario construction practices. However, the use of asbestos in Ontario construction is very infrequent, and we have been unable to find regular users of asbestos cement sheet or pipe. In all cases where protection is provided it has been through the use of personal protective devices. While special fittings and process controls for sawing and drilling have been developed by the Johns-Manville Corporation in the United States, we are not aware of their general usage in Ontario.

Examples of Control Applications

The type and effectiveness of the wide variety of asbestos controls may be seen by a series of examples. In the friction products industry it is necessary to drill holes in the brake pads or linings. This is commonly done with a group of synchronized drills which can be run pneumatically. The provision of a ventilating hood over and around the sides of this device plus a provided airflow of approximately 100 fpm will ordinarily control fibre levels close to around 1 f/cc. Failure to keep this hood very close to the process can allow the fibre levels to reach higher than 2 f/cc. If the pneumatic system exhaust is allowed to blow on the ensuing dust, then

fibre levels can rise well above 5 f/cc. Failure to allow for the removal of the dust and chips in the region can result in dust building up on the working equipment and on the floor. Good control to the 1 to 2 f/cc level commonly provides for a suction around the bottom of the drills which pulls away the chips as well as any dust. Such a device must be frequently vacuum-cleaned to provide control of the chips which do not fall into the collecting device. Failure of the air collecting device would ordinarily require that the drill be shut down. Operation of the drills without pneumatic exhaust would generally be expected to control fibre levels to 1 f/cc or, for a well-designed system, 0.5 f/cc. An attempt to enclose this process will require a device for feeding the brake linings or pads into the enclosure. Depending on the degree of automation this may require opening of the enclosure for a semi-automated process or allowance of an entry point for the brake linings or pads and an associated exit point in the enclosure. If, however, airflow rates are kept up, these openings for entry and exhaust will not allow air to seep into the working environment. A well-designed automated process which is enclosed should provide fibre level controls down to 0.1 f/cc or lower. For the semi-automated process where handloading is required, the fibre levels in the room should be kept below 0.1 f/cc during operation, and a sufficiently large exhaust would probably maintain this level during the opening of the enclosure. In the case of the semi-automated process where handloading is used such an enclosure would result in a considerable loss in productivity. Our estimate of this loss of productivity can only be approximate but would seem to be

in the order of 5 to 10 percent. The machine would remain as productive, but the amount of labour required would increase by this amount.

The grinding and finishing operation is a high producer of fibrous material and as such presents considerable control problems. Proper positioning of the air intake with consideration of particle trajectory is imperative if a 0.5 f/cc level is to be achieved. Due to the wheel-induced velocities, the particles may be expelled from the capture system even with a high exhaust rate. For this reason, special machine designs are necessary which are dedicated to a specific grinding operation. The cost of such machines may be very high, but some of the cost should be assigned as a cost of production equipment since they may also increase productivity.

Another example of asbestos control concerns the situation with gasket cutting. In some cases asbestos gaskets are cut to their proper shape by hand for custom installations. This operation results in a very small quantity of dust. Some sampling data indicate that this dust level for a full-time operator would be around 0.1 to 0.7 f/cc. As a result of this, no controls are required unless the standard is 0.5 or 0.1 f/cc. Under the circumstances these gaskets could appropriately be cut on a table whose surface has a fine array of holes pulling air downwards through the table and away from the worker's face. This would represent a capital expense to the manufacturer which would almost certainly provide extremely low dust levels.

An example of extreme difficulty in control consists of the

sawing of large sheets of asbestos cement or asbestos-reinforced plastics combinations. These materials are commonly used for laboratory table tops and electrical and heat insulator applications. The cutting must be done on large tables and requires some considerable amount of operator positioning since most work of this nature is not mass production but custom cutting. Local exhaust provided around the saw blade and the location of the cut will keep fibre levels down to 2 to 4 f/cc if very high rates of airflow are maintained. The common control method for this type of process is wet cutting. In this process a spray of water is continually directed at the cutting area, and dust in this region is minimized. A difficulty with this method is that the slurry which results is asbestos-contaminated. Spray in the general area of cutting can leave a large area contaminated with asbestos-containing water. If this water now dries in floor cracks and in parts of the machinery, then a fibre-contaminated cake is produced. Any disturbance of this cake will result in an associated fibre contamination of the air. It is our estimate based on available data that such a process could not produce fibre levels below approximately 0.5 f/cc. An alternative to this process would be to undertake the cutting in a self-contained room with the operator working in a booth during the cutting process. This would not be very satisfactory since a large amount of setup time and a small amount of cutting is required in this operation. The only satisfactory procedure would seem to be to provide the operator with personal protective devices if a fibre level of 0.1 f/cc is required.

The process of debagging has traditionally been a difficult one

to control. The operation consists of taking a large asbestos-filled plastic bag and cutting or slitting the bag open to remove the asbestos. In most applications the asbestos drops into a drum or a receiver where it is quickly wetted or contained within a controlled or sealed process. Such a process can be difficult to automate since many manufacturing systems only need occasional bags of asbestos (i.e., one to ten times per day). A large working area is needed for the operator, and he must have free arm motion since the bag is approximately 2-1/2 to 3 ft. long. The best traditional systems consist of local ventilation hoods with very high face velocities. Since the area is large, the amount of air used is also very large. This may be alleviated somewhat by only turning the ventilation system on during the actual debagging process. At the completion of the bag emptying, the empty asbestos container must be stored safely. Usually the bag contains large amounts of fine fibre at this point, and the motion of moving the bag to a garbage container or similar device can often cause considerable dust. A number of commercial devices for automating this process are available, although there is serious doubt about their reliability. At the present time we are unaware of automated debaggers in regular use in any Ontario plant. They are extremely expensive, costing approximately $50,000; however, it is our estimation that a fibre level below 0.5 would be extremely difficult to achieve without effective debaggers.

4.0 COST OF IMPLEMENTING CONTROL FOR VARIOUS MANUFACTURERS

4.1 Costing Procedures

Having discussed the feasibility of engineering controls, a determination of their associated costs is required. In this section the costing methodology will be outlined.

After a positive decision on the engineering effectiveness of a particular control system, an economic feasibility analysis must be carried out. Should such an analysis prove the cost of controls to be uneconomic, consideration would then have to be given to using asbestos substitutes, leaving the asbestos market completely, or moving out of the province. It must be noted that foreign competitors, that is, extra-Ontario manufacturers, are not all faced with equivalent regulations concerning asbestos exposure and thus are not faced with large control costs. This has important consequences on market competition. It is evident that from the manufacturer's viewpoint, the economics of control are vital.

The simplest case of cost estimation is for a "single work station" or unit process, examples of which are lathes, drill presses, bag-opening stations, grinders, mixers, etc. An example procedure, without actual costing figures, is given in Table 4.1. Components of the control system are tabulated in the lefthand column, and references, descriptions, unit cost factors, and total costs are then given across a row for each component. Determination of control costs for each component is based on the physical and operating parameters for the manufacturing process under consideration. Typical parameters are operating speed, feed rate, physical size, and work practices. The

REFERENCE KEY TO TABLE 4.1

References:

1 Kinkley and Neveril

2 Neveril

3 Rajhans and Bragg

4 Strauss

5 Research Triangle Institute

6 Industry Sources

7 Grant _et al._

8 Chemical Engineering

9 Bastress _et al._

10 Goldfield and Brandt

11 Hagopian and Bastress

12 McDermott

Nomenclature:

a/c = air to cloth ratio, bag design aspect

A/P = Capital Recovery Factor - The factor by which the initial capital is multiplied to obtain the equivalent annual payment including capital + interest at a specified rate of return and time horizon.

P/F Present Worth Factor - The factor by which an expenditure in the future is multiplied in order to obtain an equivalent present worth considering interest rate and time period.

BHP = brake horse power

BTU = British Thermal Unit, Energy Measure

c.s. = carbon steel

d = diameter

dep = depreciation

hr = hour

I = interest

L = length

n.c.a. = net cloth area

PL = pipe length

sq.ft. = square feet

wt = weight

Table 4.1 - Capital Equipment Costs

Item	Description	Reference	Unit Cost (example figures)	Cost Factor (ex. fig.)	Total
1 baghouse	intermittent mech.shaker 2:1 a/c	1,2,3,4,5	2910+1.6*nca	nca=x sq.ft.	
2 suction	option	1,2	1200+0.1*nca	nca=x sq.ft.	
3 filter bag	cotton sateen	1,2,4	.80 * nca	nca=x sq.ft.	
4 hood fabrication	c.s.rectang. 10 gauge	1,2,9	$\$=1.5L^2 + 12L + 58$	L=x ft.	
5 hood material	c.s. 10 gauge	1,2	area=$1.25L^2 + 4$ \$=L*8+0.208*wt wt=area*1.2*5.6	L=x ft.	
6 ducting	7"d .c.s.	1,2,9	\$=(1.25+.93d)PL	PL=x ft.	
7 elbow	7"d .c.s.	1,2	$\$=10.3d+.15*d^2$	d=x in.	
8 fan	bwkd.curvd. 2 kcfm,4 krpm 10" H_2O	1,2	--	--	
9 motor	4 BHP 3600 rpm	1,2	$\$=.00845BHP^2 + 60 + 11.9BHP$	BHP=x	
10 starter	magnetic w/ circuit breaker	1,2	$0.00005BHP^3$ \$=150+2.5 BHP +0.4BHP2	--	
SubTotal	Equipment	1,2			______
11 installation	75% equipment cost		--	--	
SubTotal					______
12 engineering	10% above cost	1,2,4	--	--	
SubTotal					______
13 Contingencies	10% above cost	1,2,4,6	--	--	
Total	Converted to \$CDN - 1980	8,			______

Table 4.1 (cont'd) - Annualized Costs

Item	Description	Reference	Unit Cost (example figures)	Cost Factor (ex. fig.)	Total
1) Capitalized cost	I=y % life=x yrs.	1,2,7	--	Appropriate capital recovery factor (A/P)	
2) maintenance	2% equipment cost	1,2,4	--	maint/yr=x	
3) replacement bags	5 yr. life cotton sateen	1,2,4	560 per replacement	Appropriate present worth factor (P/F)	
4) fixed charges (insurance, tax)	1-1/2% of capital cost	4,7	--		
5) housecleaning	Dependent on the industry. Values are as given to us by industry.				
6) operating	"			"	
7) makeup air heating	"			"	
9) loss in productivity	*	6	--	--	
10) value of collected material	nil	1,2,6	--	--	
Total Annual					

*Dependent on type of production

actual cost figures can then be derived from the combined consideration of reference data obtained in the literature survey and the figures quoted by Ontario industries, as well as some degree of judgement. Costs are brought up to December 1980 by means of the Process Engineering Plant cost index, and conversion to Canadian dollars was made for those references giving figures in American dollars.

Since the figures are expressed in terms of the purchasing value of 1980 Canadian dollars, a correction for future inflation is not required.

The next level of complexity is the costing of a total production system or plant. However, this is an aggregation of simple work stations with a sharing of certain control system components. Usually, for example, one baghouse complex and a major ducting manifold would be a common system component with the duct line, canopy hood, and operator training specific to the individual work stations. Costing can proceed as in the case of single work stations, and portions of the common control system component's cost can be assigned to individual work stations based on the proportion of air exhaust required by the process.

The result of assigning portions of the basic housekeeping and central air system costs to each process according to exhaust air requirements is to cause the apparent cost of obtaining a certain level of control to decrease in some cases.

Monitoring, Medical, and Training Costs

The move to lower fibre levels results in additional costs for the monitoring of fibre levels in the plant. In some of the larger industries, one individual is assigned this task and has an estimated operating expense including salary of approximately $30,000. We have estimated the expense as 1 person full-time per 600 workers, based on Ontario experience for a cost per person of $50. The monitoring cost included in the annualized cost of control for this study is apportioned accordingly.

Yearly medical examinations are required for each employee. This involves not only the medical fee of $40 but also lost time for the employee to attend a clinic. A minimum of 2 hours of non-production time at $10/hr. is assigned for this, which yields a medical surveillance cost per employee per year of $60.

Training costs are difficult to estimate as each plant should have a safety program related to all plant hazards, including asbestos-related training. For the management and supervisors, general meetings are required to administer the overall program, and these are estimated to be 1 person per 15 employees spending an hour per month. The hourly rate for this individual is considered to be $15 or, for the year, $180/15 people employed.

A distinction is made between the number of individuals exposed to asbestos fibres and an operator involved with a specific process. For example, each plant may have janitorial or maintenance staff which are exposed due to contact with the overall manufacturing system.

All costs expressed on a per person basis are, in fact, cost per

operator. Costs per total work force member would, therefore, be lower. For a two-shift operation the costs per operator would be one-half of all quoted figures. For costs per total number of plant employees including staff, the assumption that maintenance, supervisory, and cleaning staff equals approximately 25% of production workers and that office staff equals an additional 25% of production workers would enable costs per employee to be determined. In this manner, it is possible to assign a relative cost to the various processes and work forces. It is felt that this gives a clearer indication as to where control costs arise.

4.2 Costs of Control for the Friction Products Industry

Since the manufacture of friction products is an important aspect of the asbestos industry in Ontario, a detailed costing is presented in order to evaluate the impact of decreasing the allowed fibre level. The analysis is based on a hypothetical small brake plant employing approximately 30 production workers since this is the minimum size that could include the major dust producing processes. Throughout this section on control costs, reference to brake pads or shoes may be made interchangeably, although the two products are quite different: shoes pertain to drum brake systems and pads pertain to disc brake systems. The manufacturing processes involved in the production of each are sufficiently similar that they may be considered a single product for the purposes of this section. While some manufacturers have reported a roughly 50-50 split between disc pads and drum shoes, others report that up to 80% of sales are in disc pads.

Such a plant may be characterized as having the following

manufacturing stages: storage and receiving, mixing, preform presses, drilling,and grinding-finishing. The model plant is considered to have 1 mixing machine and 10 machines in each of the remaining three stages. It is felt that by choosing this simplified arrangement, it is possible to evaluate a representative costing for the industry without becoming too complex or specific to any one plant layout. Actual plants contain a larger number of employees and more processes.

The actual fibre levels found at each type of operation as taken from Ministry of Labour reports were correlated with the type of control or processing method which yielded that level. By this means, it was possible to determine the necessary equipment to achieve the fibre levels of 2, 1, 0.5, and 0.1 f/cc. In certain instances, judgement was utilized in assessing the necessary modifications to equipment in order to reach the 0.1 level. These observations are summarized in Table 4.2 and became the basis for the costing analysis. In most cases best available practice was used. There is considerable variation in actual installations.

Throughout the industry, the predominant method of dust collection was by means of a baghouse system. The procedure for establishing the overall cost then was to estimate the total flow requirements and flow losses thereby setting the size of filtration system. It was assumed that there would be one central cleaning (baghouse) system to service the entire plant. This may not be possible in large plants.

Having estimated the total required capital expenditure,the annual cost was considered. The typical rates of return were chosen

Table 4.2 - Requirements for Control in Friction Products Manufacturing and Relative Costs*
(I=10%, Life=8 yrs.)

Fibre Level	Process	Description of Control	Capital Cost	Annualized Cap. Cost	Annual Oper. Cost	# of Operators	Capital Cost/Oper.	Annual Total Cost/Operator
2 f/cc	Storage, Receiving & mixing	Manual bag opener with local exhaust	$12,600**	$2,362	$7,924	2	$6,300	$5,143
	Preform & Press	No local exhaust required	-	-	4,036	9	-	448
	Drilling	Minimal Enclosure design with exhaust	41,160	7,715	44,321	9	4,573	5,782
	Grinding & Finish	Minimal Enclosure design with exhaust	41,160	7,715	44,321	9	4,573	5,782
		TOTALS	$94,920	$17,792	$100,602	29		
		AVERAGE					$3,273	$4,083
1 f/cc	Storage, Receiving & Mixing	Immediate bag repair; general housekeeping manual bag opener with good hood or enclosure; increased face vel.	$11,025**	$2,067	$8,665	2	$5,513	$5,366
	Preform & Press	Minimal local exhaust	32,393	6,071	28,710	9	3,600	3,865
	Drilling	Good enclosure surrounding work place	47,784	8,957	45,978	9	5,309	6,104
	Grinding & Finish	Full enclosure	59,202	11,097	45,978	9	6,578	6,342
		TOTALS	$150,404	$28,192	$129,331	29		
		AVERAGE					$5,186	$5,432

Table 4.2 (cont'd) - Requirements for Control in Friction Products Manufacturing and Relative Costs (I=10%, Life=8 yrs.)

Fibre Level	Process	Description of Control	Capital Cost	Annualized Cap. Cost	Annual Oper. Cost	# of Operators	Capital Cost/Oper.	Annual Total Cost/Operator
0.5	Storage, Receiving & Mixing	Immediate bag repair; general housekeeping; tighter enclosures about the entry port and debagger; larger general hood	$128,951	$24,170	$32,098	2	$64,476	$28,134
	Preform & Press	Full local exhaust	44,130	8,273	26,718	9	4,903	3,888
	Drilling	Full enclosure	65,926	12,357	57,343	9	7,325	7,744
	Grinding & Finish	Full enclosure	65,926	12,357	57,343	9	7,325	7,744
		TOTALS	$304,933	$57,157	$173,502	29		
		AVERAGE					$10,515	$7,954
0.1***	Storage, Receiving & Mixing	Covered (protected) storage containers; increased floor space fully automated debagger and mixing set with large exhaust hood	$228,952	$42,915	$32,098	2	$114,476	$37,507
	Preform & Press	Full enclosure	79,262	14,856	26,718	9	8,807	4,619
	Drilling	Full enclosure	141,207	26,468	57,343	9	15,690	9,312
	Grinding & Finish	Full enclosure and perhaps redesign special equipment for specific finishing operations	1,676,150	314,178	57,343	9	186,239	41,280
		TOTALS	$2,125,571	$398,417	$173,502	29		
		AVERAGE					$73,296	$19,721

***Note: This level may not be achievable in practice.

Table 4.2 (cont'd) Definition of Terms Used in Costing Tables

Capital Cost - The cost for the engineering design, manufacture, or purchase and installation of equipment or system for fibre control.

Annualized Capital Cost - The annual cost of paying the principal plus interest at 10% over 8 years.

Annual Operating Cost - The yearly cost of fibre level control (i.e., maintenance, monitoring, personal protection, etc.) without the cost of servicing the capital (annual capital cost).

Notes: *All figures quoted are in 1980 Canadian Dollars.

**The apparent decrease in cost for achieving a lower fibre level is due to the manner in which the cost of the central system is assigned to each process. The assignment was made on the basis of the exhaust air requirements. As the degree of control is increased, more equipment must be ventilated. This distributes the cost of the central system over more processes.

at 10% and 20% as it was felt that these values bracketed a reasonable range which may be used in the industry. For the life of equipment, values of 3 or 8 years were felt to be appropriate since one company hoped to be completely out of asbestos products within 3 years, and 8 years allows for a realistic amortization period in light of the constant improvements of dust control equipment common in the asbestos industry.

The annualized cost includes maintenance, bag replacement (based on a 2-year life), and fixed charges all based on the estimates established in the cited references. The remaining annualized costs are based on actual data obtained from plant contacts and include such considerations as housecleaning, disposal of filtered waste, air heating, laundry, personal protective equipment, training, medical and monitoring costs. For an example presentation of such costs, see Appendix D.

With the increase in use of full enclosures, it is to be expected that worker productivity will decrease. This factor was accounted for by considering an 8% increase in man-hours for the year. This is based upon interviews and our own estimates. No attempt was made to assess the amount of additional office space or office staff required to complete medical and monitoring records. It was indicated that the employee turnover rate for people working in this area was typically 10-35% per year for some industries. This could constitute a significant burden on a company's existing staff if personnel costs for clerical duties were not increased.

The incremental capital cost incurred in moving from a 2 f/cc to

1 f/cc level is $1,913 per operator presently involved in asbestos product manufacture. If one considers the increment from 2 f/cc to 0.5 f/cc, the capital cost per operator is $7,242. The results are summarized in Table 4.3.

The cost imposed in attempting to move to the 0.1 f/cc level is graphically presented as well in Figure 4.1. This is a reflection of the fact that in order to attempt to achieve a 0.1 level consistently, a great deal of plant and equipment redesign is necessary. When the annualized costs are considered it becomes obvious that the 0.1 level, even where possible, would impose a great demand on operating capital.

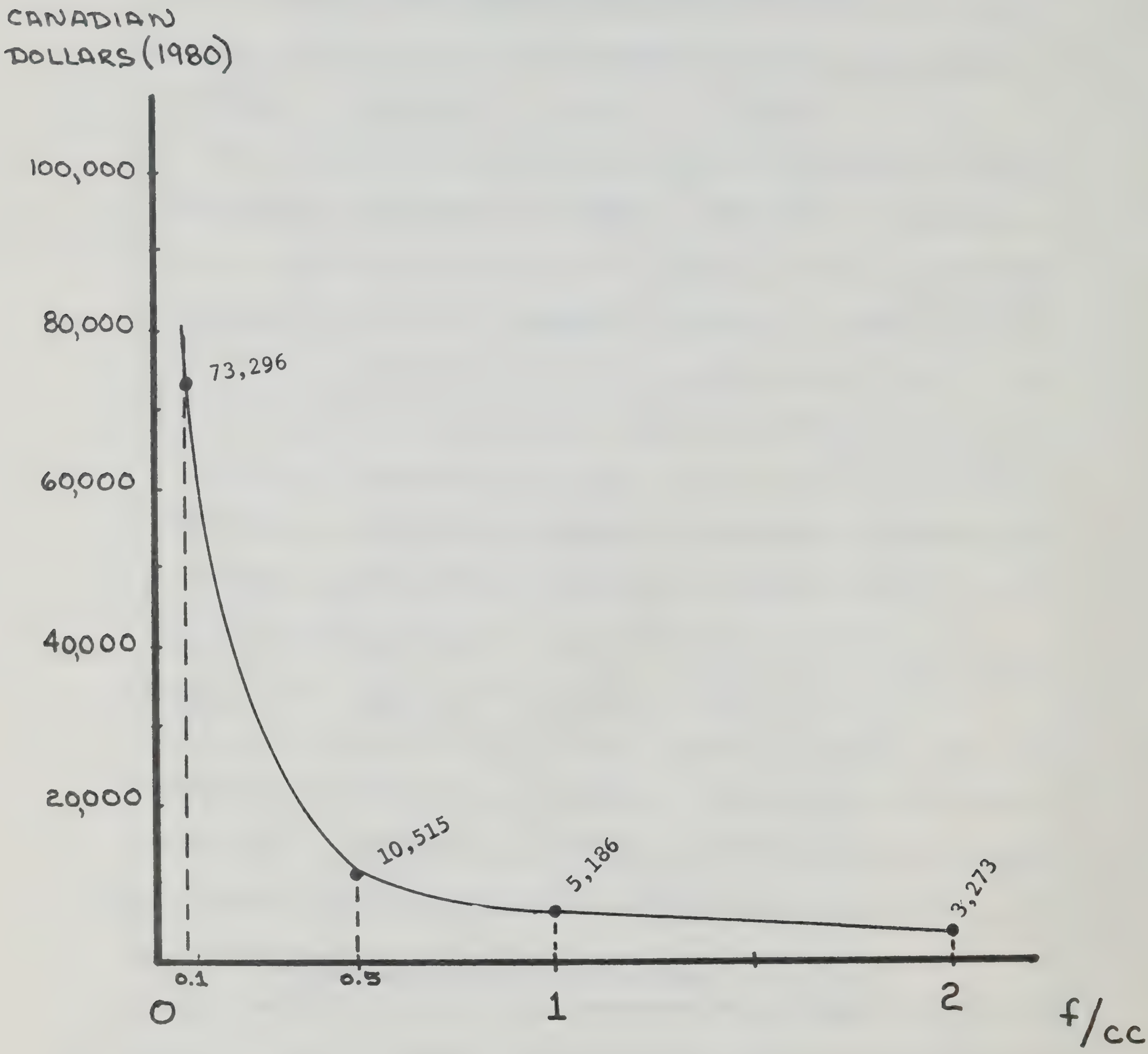
The great increment in capital costs to move to 0.1 f/cc is due to the purchase of specialized manufacturing equipment to control dust in the grinding operation. This equipment is necessary because of special hooding features incorporated into the basic design. It is possible that some of this cost should be assigned to production rather than control. If so the cost estimate is pessimistic. The increment in annualized costs required to reach the 0.1 f/cc level is mainly due to servicing of capital. Specialized production equipment for asbestos use is not common but debaggers are another example. The cost per operator for the various work stations indicates that the cost of control does not increase smoothly for each manufacturing process. This variability among processes is dependent primarily on the amount of exhaust air required and the initial capital for equipment necessary to achieve the desired level of control.

Table 4.3 - Capital and Annualized Costs in Friction Products Manufacture*

	2 f/cc	1 f/cc	0.5 f/cc	0.1 f/cc
Capital cost	$ 94,920	$150,404	$304,933	$2,125,571
Average Capital cost per operator**	3,273	5,186	10,515	73,295
Total Annualized Cost				
I=5, Life=3	134,782	182,925	283,309	951,865
=8	115,493	153,467	221,828	503,517
I=10 Life=3	137,904	187,637	293,239	1,025,335
=8	118,394	157,523	230,659	571,919
I=20 Life=3	144,470	197,631	314,155	1,178,466
=8	124,644	167,061	251,025	725,501

*All values indicated in 1980 Canadian Dollars.
**Based on 29 operators.

Figure 4.1 - Capital Cost Per Operator Versus Fibre Level For Brake Plant Dust Control



While varying the interest rates and amortization period changes the overall cost levels considerably, it does not substantially alter the relationships between the results.

One of the major sources of annualized cost, apart from that occurring from the capital expenditure, is the conditioning of makeup air. It would appear that recirculation or possibly the addition of a heat exchange system could prove highly beneficial in reducing a company's operating costs. Further study in this area would be necessary to assess the cost of implementing the system versus the annual cost savings.

Consequences of Deferred Controls

The consequences of deferring the imposition of stricter controls depend on a number of factors. In the original equipment automotive friction products industry there is considerable hope that asbestos might be eliminated from the product within 5 years; the replacement parts industry will take longer. If this happens and controls were tightened after 5 years, the costs would be eliminated rather than deferred. It is unlikely that stricter controls will hurry the substitution process since there is already a large amount of activity in this field, and the present climate is already highly favourable to substitutes.

Deferring imposition is unlikely to give time for significant technological breakthroughs in the control field in the immediate future. The costs are more dependent upon expertise and experience than upon innovative processes. For example, debaggers which function reliably might become available after a period of development. We feel

that 2 years is the minimum time over which a company could move to significantly stricter methods of control. This time is based upon an assumption of 6 months for budgeting and preliminary engineering design, 6 months for procurement and delivery of larger pieces of equipment such as bag filters (this item is very optimistic), 6 months for construction and plant alterations, and 6 months for improvement and refining of the installation. Such a timetable would be necessary for a company, say, at 2 f/cc to improve the situation to 0.5 f/cc.

The mechanism for evaluating alternatives most used by engineers is to calculate the present worth. This is the amount of money invested today at a specific interest rate which would give the required funds at the required time in the future. Such a calculation will, of course, show that a deferred expenditure is preferable to a present one if the amount of expenditure is the same. We have calculated the consequences of deferring the costs of the example friction products plant constructed to 0.1 f/cc standards for 2 years and 5 years. The results are shown in Table 4.4. The effect of buying new production equipment for grinding has been included in Table 4.4. In the case of deferred expenditure, there is a likelihood that this piece of equipment would be purchased as a part of normal production machinery replacement. This would decrease the cost of control at this level and conceivably as a result could show a lower true cost in the future.

4.3 Cost of Control for a Gasket Material Manufacturer

The asbestos industry in Ontario contains a number of producers

Table 4.4 - Benefits of Cost Deferral to Achieve 0.1 f/cc in a Brake Plant*

(8-year life, 10% interest rate)

Assume:	Estimated capital cost	$2,125,571
Assume:	8-yr. life - then total annual cost	571,919

Present Worth of 8-yr. life	3,051,188
Present Worth if deferred 2 yrs.	2,521,502
Present Worth if deferred 5 yrs.	1,894,483

*All Figures Indicated are in 1980 Canadian Dollars.

involved in the manufacture of gasketing materials both in sheet and braided forms. The purpose of this section is to examine the cost of control for the manufacturer of the material itself. The following section will deal specifically with the user of the processed material.

The packing sector of the industry involves the treating of asbestos yarn purchased from textile mills outside the province. Through braiding, calendering, and twisting operations a "rope-like" product is obtained. The fact that the yarn is treated with various substances such as graphite and teflon proves to be a significant aid in reducing airborne dust. Since the point at which this coating process occurs may differ from one manufacturer to another, no attempt has been made to estimate the cost for redesign of the industrial process.

The material for the gasket sheet is first mixed and then shovelled into a sheeting mill. This process requires a high degree of local exhaust in order to control solvent vapours used in the mix. The ventilation in this area also controls asbestos fibre levels.

Examination of the Ministry of Labour reports indicates that the fibre control in this industry is of such a nature that a major step in control from 2 f/cc to approximately 0.1 f/cc may be achieved with the use of good enclosures and exhaust systems. For the purposes of this costing study a plant employing 30 people and consisting of a compounding or mixing station, a sheeting mill, 10 braiding-twisting machines, and a spooling station was analyzed. A summary of the expected required controls is presented in Table 4.5.

Table 4.5 - Control Methods and Relative Costs for a Gasket Material Manufacturer (I=10%, Life=8 yrs.)*

Fibre Level	Process	Description of Control	Capital Cost	Annualized Cap. Cost	Annual Oper. Cost	# of Oper.	Capital Cost/Operator	Annual Total Cost/Operator
2.0	Debag, Mixing, Receiving	Hooded debagging & mixing stations	$8,143	$1,526	$6,069	3	$2,714	$2,532
	Sheeting Mill	Minimal hood design and flow rate	34,277	6,425	30,241	5	6,855	7,333
	Trimming Tables	Minimal enclosure	-	-	4,036	6	-	673
	Braiding M/C	Minimal enclosure	97,802	18,332	56,446	10	9,780	7,478
	Spooling M/C	Canopy hood	7,071	1,325	6,069	1	7,071	7,394
		TOTALS	$147,293	$27,608	$102,861	25		
		AVERAGE					$5,892	$5,219
0.1**	Debag, Mixing, Receiving	Debagging with enclosure	$6,897	$1,293	$4,552	3	$2,299	$1,948
	Sheeting Mill	Large canopy hood at 130 ft/min face vel.	52,837	9,904	45,933	5	10,567	11,167
	Trimming Tables	Complete (tight) enclosure	21,756	4,078	12,000	6	3,626	2,680
	Braiding M/C	Complete (tight) enclosure	120,241	22,538	68,969	10	12,024	9,151
	Spooling M/C	Better placement for particle capture; increased cfm	5,825	1,092	4,552	1	5,825	5,644
		TOTALS	$207,556	$38,905	$136,006	25		
		AVERAGE					$8,302	$6,996

**Note: This level may not be achievable in practice.

*All values indicated in 1980 Canadian Dollars

Since control at both levels requires the use of enclosures, the loss in productivity is considered to be the same at both levels. Housecleaning and laundry costs as well are equivalent at each level. These observations are taken into account when the annualized costs were calculated. The overall capital and annualized costs are presented in Table 4.5. Since the effect of varying rates of return and depreciation period is not expected to alter proportional costs for this industry either, only an interest rate of 10% and life of 8 years are considered. This calculation produces a middle range of values.

4.4 Cost of Control for a Small Gasket Manufacturer

Uncontrolled fibre levels are generally in the 1 to 0.5 f/cc range in the gasket manufacturing process. This low level is, for the most part, due to the fact that they need not deal with asbestos in its raw form. The asbestos is in a bound sheet form and, therefore, exposure occurs only during cutting or stamping operations.

For the purposes of costing, a small plant operation is considered which consists of presses (2), hand cutting tables (2), and sewing machines (2) employing 8 production workers. This number of machines is typical in this type of plant. Characteristically, they manufacture non-asbestos gaskets as well and, therefore, not all of the equipment needs to be modified to control the expelled asbestos fibres.

Fibre counts indicate that hand cutting operations are the worst contributors of free fibres to the surrounding area. It is felt that by controlling this operation alone, the fibre level can be reduced

immediately to the 0.1 level in the vicinity of the cutting table. Plants already have achieved close to the 0.5 level at the press and in sewing operations. The necessary hierarchy of controls needed to obtain the various levels is presented in Table 4.6.

Certain minor housekeeping practices should be adopted. After a gasket has been cut from the sheet, the remaining scrap material must be carefully discarded into plastic bags as close to the cut-out tables as possible. If the remaining material is not to be discarded but used for other products at a later time, it should be vacuumed before it is stored.

The capital and annualized costs are as given in Table 4.6. Both the capital and annualized sums appear to double as the control level moves from 2 to 0.1 f/cc. For this small size of plant it is felt that medical and monitoring costs are negligible. As well, the low fibre counts observed indicate that personal protective devices would not be necessary. With regard to housekeeping, the 0.1 level would require that each individual be responsible for the immediate area.

A vacuum cleaner could be used amongst the 8 individuals, and the production time loss would be in the range of 15 minutes per day per person.

4.5 Other Manufacturing Processes

There are a large number of industries where the packaged asbestos is debagged and immediately becomes part of a wet process. This includes the manufacture of caulking, sealants, coatings, paints,

Table 4.6 - Control Methods and Relative Costs For A Gasket Manufacturer (I=10%, Life=8 yrs.)*

Fibre Level	Process	Control Description	Capital Cost	Annual Cap. Cost	Annual Oper. Cost	# of Operators	Capital Cost/Oper.	Annual Total Cost/Operator
2.0	Press	Not required	-	-	$ 624	2	-	$ 312
	Hand cutting	Use of special surface exhausted tables	$27,359	$5,128	11,407	2	$13,680	8,268
	Sewing	Not required	-	-	624	2	-	312
		TOTALS	$27,359	$5,128	$12,655	6		
		AVERAGE					$4,560	$2,964
0.1**	Press	Local exhaust	$17,600	$3,299	$6,636	2	$8,800	$4,968
	Hand cutting	Use of special surface exhausted tables	27,359	5,128	8,848	2	12,680	6,988
	Sewing	Local exhaust	17,600	3,299	6,636	2	8,800	4,968
		TOTALS	$62,559	$11,726	$22,120	6		
		AVERAGE					$10,427	$5,641

**Note: This level may not be achievable in practice.

*All values indicated are in 1980 Canadian Dollars

and, to some extent, plastics. The processes are unlikely to produce significant dust levels after the debagging operation. For these manufacturers the costs of control are concentrated at the debagging process.

The capital costs for the debagging stations would be higher than those shown in the friction products case because economies of scale in ventilation are not realized with a single process. As pointed out earlier, the general difficulty of obtaining low fibre levels at debagging stations would remain.

Considerable detail has been given on the costing of controls for three hypothetical cases. The conclusions which may be drawn from them, however, are quite general. Specifically, the imposition of stricter controls will result in both higher capital and annual costs. In the majority of larger plants, the imposition of a 0.1 f/cc standard would result in quite large cost increases with no guarantee of success at this level. The necessity to buy special grinding machinery in this plant, we expect, will be paralleled by the necessity for special machinery in many plants if a low fibre level is required. A large increment in cost will likely occur sooner in the case of small plants since large incremental amounts of engineering time will be necessary. The situation with respect to deferred costs will be that a deferred cost is preferable to a present cost. We would again expect special situations with respect to replacement of production equipment and availability of substitutes to affect any decisions.

Costs do not rise linearly with an increase in plant capacity. A

general rule frequently used in cost engineering is that:

$$\text{Cost for Plant a} = \text{cost for plant b} \times \left(\frac{\text{capacity of plant a}}{\text{capacity of plant b}}\right)^{0.6}$$

As can be seen, control per employee or control per unit capacity tends to be cheaper for the larger plants.

The accuracy and reliability of our calculations depends, to a considerable degree, upon our assumptions. We feel that while the actual numerical values may be open to some degree of error, the relative values are likely to remain. Specifically, we feel that the considerable increase in cost experienced at the 0.1 level would remain in all cost calculations. Also, these are minimum costs since equipment cannot always be guaranteed to perform as designed and design capability varies.

4.6 Costs for Mining and Milling

There is little mining or milling of asbestos in Ontario at the present time. The history of asbestos mining in the province indicates that these mines tend to be small open pit operations, typically of ten to twenty workers. Generally, the operations involved in open pit mining consist of drilling, blasting, and then removal of the ore by loader and truck to the mill. Milling operations consist of grinding, sieving, separation, and packing in containers. In open-pit ore bodies, modern drilling rigs can be operated from enclosed booths. Blasting would need to be done in the open air but loading and trucking can be done in enclosures. As a result we would estimate that with the exception of blasting crews,

enclosures costing approximately $5,000 to $10,000 per operating station would provide fibre levels at 0.1 f/cc except while entering and leaving the work area. It is expected that blasters would have to wear personal protective devices in the presence of high fibre levels.

The milling operation is the dustiest of all asbestos processing activities. The most modern mills are capable of producing dust levels averaging 2 f/cc. To achieve this, total enclosure is necessary at all work stations except bagging. The most modern bagging operations keep dust levels to the 2 to 5 f/cc level by heavily compressing the asbestos before packaging. It is our estimation that only personal protective devices could provide fibre levels below 2 f/cc for personnel in present asbestos mills.

Wet milling processes have been used in the United States and Australia. These processes are not usable in Canada because the addition of water destroys the product for most uses of the Canadian fibre.

4.7 Construction Costs

In Ontario the major exposures to asbestos in construction will occur during the cutting and manipulation of asbestos cement pipe and asbestos cement sheet. Use of asbestos cement products in the forms of sheet or pipe is infrequent in Ontario. We were unable to find any recent construction activities using this material. As a result the information in this section reports the findings of other investigators.

Cutting or sawing may be done with both materials and drilling is a common practice in the case of sheet. Dust levels occurring with

the use of this equipment have been reported in Wright et al. (1978), Johns-Manville (1978), and Asbestos Information Association/ North America (1980) (see Table 3.1). Special cutters are available for asbestos cement pipe. Local exhaust ventilation attachments for saws are available both for this purpose and for cutting of asbestos cement sheet. Their Canadian cost, with associated vacuum and HEPA (high efficiency particulate air) filter, would be approximately $4,000. Work of this nature is quite irregular, and it would be expected that one worker would use this equipment a small proportion of the time on most construction jobs. These saws, when properly used, have been able to control fibres to a 2.0 f/cc level. The cutting tools for pipe cost approximately $1,500 and have been reported to produce fibre levels of 0.2 f/cc. Local exhaust ventilation for drills with the associated high efficiency particulate air filter vacuum cleaner would cost approximately $4,000. Again, this arrangement has been reported as achieving 0.1 f/cc. This equipment requires considerable operator training for proper use. The Wright report indicates that this equipment may well be suitable for lower fibre levels; however, we feel that this is likely to be a strong function of operator training. Since most other construction activities appear to present little hazard and, as reported in Section 5, both asbestos cement sheet and pipe are candidates for replacement in Ontario, it is improbable that there is any innovative work being done on the problem of asbestos control during construction. Again, asbestos usage is so infrequent in Ontario construction that we have been unable to find more information on the subject.

4.8 Encapsulation and Removal Costs

There are two steps in the encapsulation process. The first step is the application of a penetrating material of a type approved by Public Works Canada for encapsulation processes. This penetrating agent encapsulates the asbestos to a depth of approximately three-quarters of an inch. The fibrous types of fireproofing are much more easily penetrated than the cementitious types. The second optional process is the application of a bridging material. This is a decorative, latex-like layer which completely coats or seals the surface of the insulation or fireproofing. A yearly visual check of the completed process is recommended for maintenance personnel. Damage is usually easily noticed and may be quickly corrected by retouching the damaged area.

Present prices for encapsulation are of the order of $1 to $5/sq.ft. of surface covered,not including preparation time and provision of alternative space during the process. Dr. Don Pinchin is doing a detailed study on this and other building-related matters and further discussions in these areas may be expected in his study for the Commission.

Removal of asbestos is a considerably more sophisticated process requiring trained personnel. The process consists of isolating the area where removal is to occur, preventing access to all unqualified personnel, provision of extensive personal protective devices for those present, wetting of all asbestos during removal, and sealing of the removed asbestos in airtight packages before removal from the

contaminated area. A thorough cleanup job is necessary in the immediate surroundings of the cleaned area after the asbestos is removed. Complete removal is seldom possible in buildings. This is because asbestos has frequently been sprayed on the basic structural members of the building which are then encased in brick walls and other permanent fixtures. Quoted prices for removal of asbestos range around $4 to $12/sq.ft. currently.

The total cost of a removal program may be considerably more than the basic removal costs since lost production time in the affected building must be taken into account. One Ontario school board has been quoted as having paid a total cost for temporary locations for children, equipment removal, and other items during the removal process of approximately $12/sq.ft. A guide to the process is given by Sawyer and Spooner (1978) and by the Ontario Ministry of Labour (1981). Asbestos removal in ships is accomplished in a similar manner by specialized personnel.

In all cases the fibre levels can be extremely high even with proper wetting. As a result personal protective devices represent the only control method within the contaminated area. In addition the location where removal is undertaken prohibits complete sealing off of the area and some contamination of adjacent areas will always occur so that considerable cleanup is necessary after a removal project.

4.9 Building Maintenance Costs

During regular maintenance of buildings with friable asbestos or asbestos which has previously been capsulated, there is a need to provide for asbestos control during occasional contact or small

quantities of removal. An example would be the installation of wiring for a light switch. The costs for adequate control in this situation would be fairly nominal. For this process typical equipment required would be:

(a) disposable coveralls;

(b) disposable or cartridge-style respirator;

(c) wetting bottle containing water with a surface-active agent;

(d) brushes and containers for cleanup;

(e) plastic bags for removal.

It is estimated that a complete set of equipment of this type would cost under $500. If this type of work is done regularly, cleanup could be facilitated by a HEPA vacuum cleaner costing approximately $3,500. An additional requirement is for all maintenance personnel to be aware of asbestos problems in contaminated buildings.

4.10 Brake Maintenance Costs

Brake maintenance in small garages requires the removal of asbestos-containing dust and occasional small amounts of grinding. If air hoses are used for cleaning, the removal of the fibre can give fibre levels between 2 and 30 f/cc and the grinding operation can cause fibre levels above 5 f/cc. The majority of brake lining replacement occurs in the summer when the doors of small garages are frequently open. This can alleviate the work area problem to some extent but may create an environmental problem. Vacuuming the dust with an industrial vacuum cleaner is unsuitable since the filters on this type of vacuum cleaner are not appropriate for very low dust

levels; we estimate that such a procedure might well produce fibre levels around 1 to 2 f/cc. A more appropriate method is brake shoe spray which is a liquid, containing a surface-active agent that is sprayed into the area where dust is to be cleaned so wet removal may take place. The cost of this is $4.40 per 450 gram can on a brake replacement task which may cost approximately $80. Removal can then be to a bowl or tray. Brake washer systems are also available for approximately $200 which consist of a liquid spray hose, sump and trolley. Measurements are not available but we would expect these last two processes to keep fibre levels below 0.1 f/cc. Both are less expensive than HEPA vacuum cleaner systems which are commercially available.

4.11 Costs of a Substitution Program for Product Users

The availability of substitutes is outlined in detail in Section 5 of this study. Ontario Hydro is an example of an asbestos product user where a substitution program was implemented some years ago. As pointed out in Section 5 this does not imply total substitution but rather elimination of asbestos insulation and all crocidolite asbestos. The cost of substitute insulation material was more expensive in the 1970's but is reported by Hydro to be cost competitive at the present time. It would seem that a considerable amount of staff time was spent in implementing the asbestos removal program. However, according to the information available, present activities consist of monitoring the availability of asbestos substitutes and careful control during asbestos removal. We would estimate that as a result of the decrease in asbestos usage there is

less medical surveillance, industrial hygienist activity, and less necessity for monitoring. As a result we feel that the added costs of substitute monitoring would be approximately balanced off by the decrease in necessity for control measures. If so, the present cost of this program is either zero or could represent a small economic benefit. The situation with particular alternative substitutes and their economic impact is dealt with further in Section 5.

4.12 Conclusions

In general, industrial processes are more susceptible to control than are construction and removal projects. In the industrial situation costs for control rise steeply at the 0.5 and 0.1 fibre levels where these are achievable. For construction and removal projects the necessity to use personal protective devices places a ceiling on the costs. Both in industry and in construction there are a number of instances where engineering controls are not effective; nor are engineering controls foreseeable. Under these situations personal protective devices or substitutes must be considered. It should be noted that dust collection equipment may be necessary for substitute materials even if they are only considered nuisance dusts.

5.0 SUBSTITUTES

It is apparent that there is a move away from asbestos due to an awareness of its toxicity. In our contacts with industry, suppliers, and users of asbestos, we have been told, for example, that usage in filtration, gaskets, packings, disc brake pads, and heat resistant sheeting has dropped off in the last year or two. Substitution programs are far advanced in some areas of application but are not effective in others. The rationale behind substitution depends on a number of factors which determine the rate at which substitution is implemented.

Costs are generally considered the most important factor in substitution. Asbestos is known to be an inexpensive material compared to many alternatives. This has been the case in situations where asbestos is used as a filler and binder in, for example, floor tile. In this case a possible alternative is talc which is now reasonably competitive on a price basis. In the case of asbestos cement sheet and pipe a possible substitute in many cases is glass fibre reinforced cement which is approximately twice as expensive and has a much shorter life. For pipe there is a trend toward plastics which, in some cases, is cheaper. The necessity to handle asbestos carefully also increases its processing costs. The effect of this is dealt with extensively in Section 4 of this study.

Another important factor in substitution is the amount of research being done to determine the properties and feasibility of application of alternative raw materials. The vast majority of work in this field is being done in the United States. Because the

properties of asbestos are unique, no single alternative material can be considered. As a result the breadth of this research is quite large, and superficially quite different materials are being considered for substitution in different applications. Details of this research were outlined in the National Workshop on Substitutes for Asbestos held in the United States (U.S. Environmental Protection Agency, 1980). The discussions presented in the proceedings of the Workshop are particularly instructive concerning the problems of finding effective substitutes. In many cases substitutes are more expensive or have rather different properties. In a few cases cheaper materials have been discovered. As a result of the research done in the United States it has been stated (U.S. Environmental Protection Agency 1980) that all disc brake pads will be non-asbestos by 1985. At the present time no obvious alternative has been found in the case of brake drum linings. Athough new products are being developed constantly, alternatives to drum linings considered to date are more expensive, show brake fading properties, cause brakes to squeal, and have problems in their manufacture. For this application some materials being considered are up to twenty-five times more expensive than asbestos, resulting in a product up to two times as expensive. The work being done in this field is fairly fundamental in nature and deals with the basic properties of materials and the properties in combination with other materials. Also, redesign of the entire braking system may be necessary. We are not aware of any significant quantity of fundamental work being done in this field in Canada.

An important aspect of replacement is customer acceptance.

Customers for asbestos products (industries or consumers) may favour asbestos or asbestos replacements. For industrial customers the desire to eliminate asbestos has provided the impetus for suppliers to provide non-asbestos products. In some cases--Ontario Hydro is an example--they are prepared to pay up to four times as much for a non-asbestos duct expansion joint. Some industrial customers insist on asbestos-based products. Examples of such products are fireproofing and laboratory table tops where the extreme heat resistant properties of asbestos are desirable. The properties of asbestos-based pump packings also are unique in terms of their heat resistance in special applications. The situation as far as customer acceptance in the consumer field is rather different. With the present widespread knowledge available with regard to the danger of asbestos, such items as asbestos insulation in hair dryer insulators have been removed from the market. However, consumers are not generally aware of the presence of asbestos fibre in floor tile. As a result there is little consumer resistance to this tile. Similar ignorance of the presence of asbestos can occur in some of the smaller industries as well; this is particularly true when materials are bought as proprietary brands.

Competition from outside the province and import/export factors can have an effect on substitution. For example, an Ontario floor tile manufacturer pointed out that since the island of Formosa does not produce asbestos, asbestos products are imported duty free into that country. In addition,he pointed out that Quebec purchasers of floor tile, particularly government purchasers, favour floor tile with a maximum asbestos content. This particular manufacturer supplies

both these markets as well as being interested in American markets which are asking for floor tile with no asbestos.

The political environment and the effect of the media are also forces affecting the substitution programs. Some companies have indicated to us that while they personally consider asbestos to be safe in the locations and with the methods which they presently have in use, they propose to discontinue asbestos use as soon as possible in order to be seen as good citizens.

The regulatory framework both in the province and outside it is also an important factor in substitution. It is obvious that industry is, to some extent, mobile and those manufacturers wishing to continue producing asbestos products, who have trouble meeting the Ontario legal requirements for safe use, may move. Conversely, those manufacturers who wish to stay in a regulated environment will look more carefully for substitutes. As may be expected these two hypothetical organizations will remain in competition with each other. If an asbestos and non-asbestos product have a significant price differential, then a more expensive non-asbestos product produced in Ontario will be at a severe disadvantage when competing against non-Ontario asbestos-based products. It will be obvious that stricter regulations implying greater expenditures in control will increase the probability that substitution becomes economic.

The effect of an educated work force can be to discourage asbestos use. A number of asbestos users have been discouraged from using the material by union and employee complaints, according to our information.

The danger that a company using an asbestos product may be sued for damage to the health of its workers and customers is a powerful incentive to substitute asbestos. While this aspect of substitution is prevalent in the United States we have been informed by at least one American-owned Ontario manufacturer that this is the fundamental reason for the company attempting to move away from the use of asbestos in all its plants worldwide. It should be noted that in the meantime the majority of asbestos production for this company has been shifted to Ontario. This would seem to be a temporary measure until asbestos can be eliminated entirely from the product line. It is obvious that the financial consequences of legal action can potentially be much greater than all other economic forces combined.

The final aspect of substitution is that it can be strongly influenced by forces completely outside the province. If, for example, the United States prohibited asbestos in any application, then all Ontario manufacturers producing that product would be constrained to produce a non-asbestos product if they wish to export to the American market. Furthermore, asbestos users in Canada would tend to be influenced by the resulting products available in the United States.

Many factors affect and will continue to affect both substitution and the rate at which it is implemented. Asbestos usage has been eliminated from many applications, and it is being eliminated from many others. Drum brake linings, however, are a major product for which there is no satisfactory substitute in production. There is general agreement in the literature that all alternative brake shoe

material is inferior to the present product and, in most cases, considerably more expensive. However, new information and new products are being made available constantly, and some manufacturers claim to have substitutes ready for the original equipment market.

In some uses asbestos is unique. It is generally agreed that asbestos-based filters are more efficient than any alternative whatsoever and are particularly efficient at filtering asbestos! Furthermore, in special applications dealing with fire and high temperature resistance, asbestos is better than any other material. These latter applications, however, contain small quantities of asbestos and are not used directly by consumers.

Another example appears in the manufacture of acetylene welding tanks. The interior of the tank is a solid, porous mass which contains long fibre asbestos. Only four companies in North America manufacture this product and one is represented in Canada. We are informed that no replacement fibre of any sort has been successful to date. The asbestos is bound and is unlikely to be released during usage of the tank.

Dates for the expected elimination of asbestos in specific products are hard to produce. However, a number of brake friction material manufacturers in the United States have indicated, without describing the probable replacement material, that asbestos will be entirely absent from original equipment disc pads and drum brake linings by 1985 (U.S. Environmental Protection Agency 1980). Production of replacement parts might continue for a number of years.

Some particular examples based upon interviews with industrial representatives will indicate the problems involved at present in achieving substitution. A floor tile manufacturer informed us that they were very close to being able to produce an asbestos-free floor tile. The replacement material, if purchased, would actually be cheaper than the asbestos presently used. There was considerable concern, however, that tremolite, which is an asbestiform mineral, was a contaminant in the replacement material. They do not intend to change to this material at present because of a fear that new regulations would place a total ban upon use of tremolite.

The situation with respect to Ontario Hydro has already been outlined in Section 4. As was noted there, no asbestos is being used for insulation. However, Ontario Hydro still specifies some asbestos-containing gaskets, finds asbestos-containing floor tile acceptable, and has not moved to total elimination of existing asbestos insulation.

A third case consists of an insulation manufacturer who, some years ago, had a considerable amount of difficulty in achieving low fibre levels in the manufacturing plant. This company built a new plant to produce entirely non-asbestos insulation.

The construction industry deals with many of the previously mentioned products. The situation concerning floor tile has already been mentioned. Two major applications where dust levels may be significant are in the installation of asbestos cement pipe and asbestos cement sheeting. In the case of asbestos cement pipe a survey of city engineers in Ontario has indicated that at the present time asbestos cement pipe is more expensive than plastic pipe for the

smaller sizes. Asbestos cement pipe is not used in the larger sizes at all. A number of engineers contacted indicated that it had been some years since asbestos cement pipe was specified. Its advantages in the past were seen to be a smoother surface for sewer applications in flat locations. Those cities surveyed indicated that dust controls had never been used and that the pipe was seldom installed any more. We have been informed that almost all asbestos cement pipe usage is in western Canada and the western United States.

Asbestos cement sheet is infrequently used for siding in industrial buildings in Ontario. Installation of this sheet requires sawing and drilling operations. There are many available substitutes for this type of installation, but we have been unable to determine the rate at which substitutes are being chosen in this particular application. Again, usage in Ontario appears to be very small.

6.0 CONCLUSIONS

The conclusions summarized here are based upon interviews with asbestos producers, manufacturers and users, their technical staffs, and the information reviewed in Section 2 which is applicable to Ontario. It should be emphasized that all calculations and figures given in this study represent the best control practice observed. This best practice may require considerable expertise in its implementation. As a result, even for the cases cited in detail, some companies may be faced with spending considerably more money than that suggested in our calculations. All fibre levels reported are based upon the membrane filter method where levels below 0.5 f/cc are questionable.

Our overall finding is that the quality of asbestos dust control in industry is considerably improved over the last three to five years. This is due to the increase in application of known control technology rather than to the development of new control technologies. As a result, our conclusions are different from the most recent report which covered the technological aspects of dust control (Daly *et al.* 1976). In the Weston report it was stated that "best available technology will not achieve 0.5 f/cc TWA in secondary industries." We have found some secondary industries capable of producing fibre levels consistently at or near this level; however, this capability has only been achieved in the last year or two and, typically, for processes with low emissions originally. On the other hand, a number of specific processes are not capable of achieving fibre levels below 2 f/cc with engineering controls.

With respect to the cost of control, our studies indicate similar costs to those found in previous studies but with significantly higher costs for the lower fibre levels (0.5 f/cc and 0.1 f/cc) where they are achievable.

Our findings further suggest that:

(a) There has been an enormous improvement in the reduction of industrial fibre level concentrations over the last five to ten years. The fundamental reason for this has been a considerable increase in the expertise of those attempting the controls. Although there have been few or no technological breakthroughs in this field, many of the best practices have been adapted from other fields where the toxicity level of the material being handled is much higher than that of asbestos.

(b) There are a small number of processes which we believe cannot be controlled by engineering controls below 2 f/cc. Specific examples are dry asbestos milling, removal of friable asbestos, and, possibly, debagging.

(c) Control of dust emissions to the 0.1 f/cc level, where possible, would require extensive redesign and rebuilding of control systems. For some industries purchase of new production equipment would be necessary, making this level of control significantly more expensive than the higher levels.

(d) While purely technical considerations imply that 2 years is the minimum time to move to significantly lower control levels, the very

large expenditures necessary would require longer times so that the large amount of capital necessary could be accumulated.

(e) The lack of a proper monitoring device for asbestos fibre levels presents one of the greatest technological problems restraining achievement of good asbestos dust control. For example, if a 0.1 f/cc standard were to be maintained, then the capacity to measure levels below this is necessary.

(f) Best available technology in asbestos dust control is now approaching that for beryllium which is the most toxic solid in industrial production.

(g) Because of equipment failures and human error, it is impossible to guarantee achievement of a specific fibre level at all times. This point is particularly important when considered along with the fact that true time-weighted averages are very seldom available due to monitoring difficulties.

(h) General hood-type local exhaust ventilation is not capable of providing dust control levels beyond approximately 2 f/cc in most machining operations.

(i) Industries which have enclosed those processes capable of enclosure have obtained significant decreases in fibre levels; in some instances, this has produced plant environments consistently at a level of 0.1 f/cc. Total enclosure is limited by the necessity to allow worker contact with all processes if only for maintenance and enclosure cleaning.

(j) At low fibre levels, maintenance of enclosed equipment requires personal protective devices and a high level of housekeeping control. Workers committed to full-time maintenance would be required to spend large amounts of time wearing respirators. Achieving fibre levels below 1.0 f/cc would require a significant number of personnel (maintenance, cleaners, etc.) to wear respirators constantly.

(k) The dustiest operation in most plants remains the debagging operation. It is not susceptible to enclosure except by the use of automated debaggers which are unreliable and expensive. We have been unable to determine what fibre levels can be achieved by automated debaggers.

(l) There are unlikely to be many significant innovations in the field of asbestos control in the foreseeable future. Advances have come from improvements in the application of existing knowledge.

(m) Achievement of low fibre levels is both easier and cheaper in some industries than in others. Fully automated processes are typically easier to enclose than hand operations. The implementation of stricter levels of control would give a strong competitive advantage to those companies presently having considerable expertise in the control field. This expertise lies, typically, with the larger organizations and is heavily dependent upon a detailed knowledge of the process being controlled.

(n) Low employee exposure levels can be achieved by the use of personal protective devices. This is, however, undesirable for reasons of comfort and permanent safety in most applications.

(o) Customer knowledge and preference both at the industrial and consumer level as well as future liability and government regulation are forcing asbestos substitution more quickly than a narrow economic analysis would indicate.

(p) With the exception of a few highly technical uses, most manufacturers are actively looking for substitutes.

(q) Asbestos will remain a specialized component in certain industrial products. For example, these include acetylene tanks, certain types of fireproofing, gasketing, and filters.

(r) In the construction industry, local exhaust ventilation of the low volume, high velocity type is not commonly used. However, asbestos cement products and asbestos roofing compounds are seldom used in Ontario.

(s) Asbestos insulation removal is an activity which will continue for a long period. Since every installation is physically unique it is very difficult to provide standardized and safe removal practices. There is considerable activity in this field in the United States. We believe, however, that personal protective devices are necessary for this operation on a permanent basis and that as far as possible procedures should be codified.

(t) In a large majority of buildings, the places where asbestos has been sprayed makes total removal or total encapsulation very difficult.

(u) Dry milling of asbestos cannot be controlled by enclosures to a level much below 2 f/cc. The only other alternative is wet milling which is unsuitable for most applications. Achievable fibre levels for wet milling are unknown.

(v) The effect of implementing stringent controls over a short time frame is likely to cause a number of industries to move out of the province.

Appendix A - Bibliography

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Appendix B - Extracts from Report prepared by Research Triangle Institute

Appendix B-1

September 1978

From pages I-8 - I-9:

Primary Manufacturing

For all primary manufacturing segments of the asbestos industry, available, proven control measures and work practices which could be used now to better advantage to assure low exposure levels include the rigorous application of well-known methods, such as:

- Maximum use of local exhaust ventilation system;
- Regular performance checks and preventive maintenance on local exhaust systems;
- Immediate clean up of spillage and floor accumulation of asbestos containing solids using central vacuum-cleaning systems;
- Floor cleaning at least once per shift with a power-vacuum unit--preferably combined with wet floor cleaning; and
- Mechanically supplied, contaminant-free makeup air (tempered relative to ambient conditions) in sufficient volumetric flow rates to balance the combined local exhaust capacity in a given work area.

These control measures, together with the consistent, exacting application of control measures described in Chapter VI and summarized in Table VI-1, will achieve and maintain exposure levels as follows:

Product Segment	Currently Achievable Exposure Level (TWA)
Asbestos-cement pipe	0.4 f/cc
Asbestos-cement sheet	0.4 f/cc
Friction materials	0.5 f/cc
Vinyl-asbestos floor tile	0.3 f/cc
Asbestos reinforced plastics	0.3 f/cc
Asbestos paper products	0.3 f/cc
Asbestos paints, coatings, & sealants	0.4 f/cc
Asbestos packings & gaskets	0.4 f/cc
Asbestos textiles	
Conventional processing	1.5 f/cc
Wet processing	0.3 f/cc

After a careful review of currently attainable and reported exposure levels and advancing control technology and related

reductions in exposure levels, it is concluded that, with one exception, the primary manufacturers of asbestos products can generally achieve average exposure levels of 0.2 f/cc TWA using both the best application of techniques now available and new technology likely to be implemented within the next 2 years. This new technology includes utilizing automatic bag-opening units at all fibre opening stations. The exception is the dry-woven textile segments, where it is believed that exposure levels cannot be reduced below 1.0 f/cc without major breakthroughs in new processing technology. Where this kind of breakthrough has occurred in the textile segment (development of the wet process used by one of the asbestos textile manufacturers), exposures may be reduced to an average of 0.2 f/cc.

It is further concluded that achieving 0.1 f/cc average exposure levels is technically unfeasible even with the application of best available technology. This determination rests largely with the inability to reduce exposures in primary manufacturing industries (other than dry-woven textiles) where raw fibre is being received, stored, and handled and where finishing operations are conducted with manual materials handling procedures. In such instances, it is believed that worker carelessness, control systems malfunctions, inadvertent spillages, and less-than-perfect work practices will result in a finite background fibre concentration upon which even slight exposures from plant sources--mainly in the fibre handling and finishing operations--will yield average TWA exposures on the order of 0.1 to 0.3 f/cc.

A recently published study (Rajhans and Bragg, 1975) involving extensive sampling over a 6-year period in five asbestos plants in Ontario concluded that a limit of 2.0 f/cc is realistically achievable with present types of controls (local and general ventilation, housekeeping) but that this limit is not achievable 100 percent of the time. The study also concludes that exposure limits of 0.5 and 0.1 f/cc can be achieved (again, not 100 percent of the time) only with order-of-magnitude increases in dust collection efficiencies such as those achievable with the use of totally enclosed processing, all wet processing, or some similar technology.

Appendix B-2

Table I-2 Compliance Capital Costs for the Asbestos (Primary and Secondary) and Construction Industries ($\$10^6$)

Industry		1.0 f/cc	0.5 f/cc	0.1 f/cc
Primary Manufacturers		4.1	17.8	61.3
Secondary Industry		30.0	32.1	37.7
Automotive Aftermarket		0.1	2.3	7.9
Shipbuilding		0	0	0
Secondary Fabricators		29.8	29.8	29.8
Construction	min.	29.9	31.1	99.0
	max.	42.9	45.9	196.5
Total	min.	64.0	81.0	198.0
	max.	77.0	95.8	295.5

Table I-1 Total Annualized Cost of Compliance with Proposed Standard for Asbestos

Segment of Industry	Cost ($ Millions) at Exposure Limit of		
	1.0 f/cc	0.5 f/cc	0.1 f/cc
Primary manufacturing, 3 shifts	17.0	24.5	60.5
Automotive aftermarket	140.0	140.0	151.0
Shipbuilding and Ship Repair	2.5	2.5	2.5
Secondary Fabricators	11.8	11.8	17.8
Construction	98.0-106.1	123.8-132.7	360.7-395.1
Totals min.:	269.3-	303.6-	592.5-
max.:	277.4	312.5	626.9

Appendix B-3

Table I-5 Price Increase as a Percent of Sales For the Asbestos (Primary and Secondary) and Construction Industries

	1.0 f/cc	0.5 f/cc	0.1 f/cc
Primary Manufacturers	0.71	1.07	2.85
Secondary Industry	1.33	1.34	1.47
Automotive Aftermarket	2.5	2.5	2.7
Shipbuilding	0.05	0.05	0.05
Secondary Fabricants	1.0	1.0	1.4
Construction I* min.	0.053	0.067	0.194
max.	0.057	0.071	0.212
Construction II* min.	0.055	0.070	0.205
max.	0.060	0.075	0.223

*Construction I price increases are those that result from the imposition of the proposed standard in the construction industry alone. Construction II increases result from the simultaneous imposition of the proposed standard on general industry and the construction industry.

Appendix B-4

Table I-7 Compliance Capital Costs as a Percent of Construction Output (Revenue) for the Six Construction Types with the Largest Capital-Output Ratios (Cents per Dollar of Output)

		1.0 f/cc	0.5 f/cc	0.1 f/cc
Private Multi-Unit Residences	Min	0.046	0.047	0.137
and Non-Housekeeping Units		0.062	0.064	0.237
Residential Additions and	Min	0.031	0.032	0.101
Alterations	Max	0.046	0.047	0.197
Educational and Religious	Min	0.055	0.056	0.151
Facilities	Max	0.069	0.071	0.223
Public	Min	0.105	0.106	0.279
Housing	Max	0.131	0.133	0.408
Miscellaneous Public Con-	Min	0.030	0.031	0.093
struction, Including	Max	0.039	0.041	0.148
Military Facilities				
Demolition	Min	0.0	0.015	0.122
	Max	0.0	0.287	2.369
Weighted Average	Min	0.016	0.017	0.053
	Max	0.023	0.025	0.106

Appendix B-5

Table I-8 Output Reductions in the Primary Asbestos and Construction Industries ($ Millions)

Industry		1.0 f/cc	0.5 f/cc	0.1 f/cc
Primary Mfg. (Total Impact)*	min	1.405	1.107	4.517
	max	1.509	1.714	4.956
Primary Mfg. (Gen'l Impact)	min	.110	.166	.438
	max	.110	.166	.438
Primary Mfg. (Construction Impact)	min	1.295	1.441	4.**
	max	1.399	1.548	4.**
Construction II (Total Impact)*	min	289.953	325.101	901.641
	Max	311.598	347.177	996.290
Construction I (Construction Impact Alone)	min	274.355	301.951	838.165
	max	296.000	324.028	932.314
Total (Total Impacts)	min	291.358	326.708	906.158
	max	313.107	348.891	1,001.246

*Total impacts result when the proposed standard is imposed simultaneously on general industry and the construction industry.

**Figures illegible

Appendix B-6

Table I-11 Total Employment Reduction by Category Due to Construction Industry Contraction (0.1 f/cc Exposure Limit with Maximum Worker Exposure)

	Employment Reduction (10^3)	Percent of Precontrol Employment	Percent of Total Employment Reduction
ALL INDUSTRIES	30.90	0.42	100.0
Construction Industry	15.06	0.42	48.74
Total On-site	13.02	0.42	42.14
Carpenters	3.45	0.57	11.17
Electricians	.96	0.34	3.11
Brickmasons & Stonemasons	.91	0.51	2.94
Plumbers	.79	0.56	2.56
Painters	.60	0.60	1.94
Other	6.31	0.35	20.42
Total Off-site	2.04	0.47	6.60
Other Industries, total	15.84	0.43	51.26
Manufacturing	9.20	0.42	29.77
Other	6.64	0.43	21.49

Appendix B-7

Employment Changes in The Primary Asbestos and Construction Industries

Industry		1.0 f/cc	0.5 f/cc	0.1 f/cc
Primary Manufacturing (Total Impact)*	min.	+282.1	+280.9	+257.6
	max.	+281.1	+280.0	+253.4
Primary Manufacturing (Asbestos Industry Impact)		+294	+294	+294
Primary Manufacturing (Construction Industry Impact)	min.	-11.9	-13.1	-36.4
	max.	-12.9	-14.0	-40.6
Construction II* (Total Impact)	min.	-8,970	-10,070	-27,980
	max.	-9,640	-10,750	-30,900
Construction I (Construction Industry Impact)	min.	-8,490	-9,350	-26,020
	max.	-9,160	-10,040	-28,940
Total Impact*	min.	-8,688	-9,789	-27,722
	max.	-9,359	-10,470	-30,647

*Note: Total Impacts result from the simultaneous imposition of the proposed standard in general industry and the construction industry. Construction Impacts result from the application of the proposed standard in the construction industry alone.

Appendix C - Extracts from Report prepared by Weston Environmental Consultants

Appendix C-1
Asbestos Fiber Usage and Percent of Coverage of Each Industry Segment

	Industry Segment	% of U.S. Asbestos Usage	Tons Consumed	Tons Represented by Survey	% of Coverage	Companies Responding to Survey	Plants Covered by Survey
1	Asbestos Paper	38.0	342,000	182,000	53	12	17
2	Asbestos Cement Pipe	16.0	144,000	144,000	100	4	13
3	Floor Tile	12.5	112,500	43,400	39	5	9
4	Friction Products	6.5	58,500	35,100	60	12	13
5	Paints, Coatings and Sealants	7.5	67,500	20,500	30	16	26
6	Asbestos Cement Sheet	6.0	54,000	48,000	89	6	8
7	Gaskets and Packing	3.0	27,000	11,000	41	7	7
8	Asbestos-Reinforced Plastics	2.0	18,000	9,900	55	5	5
9	Asbestos Textiles	1.5	13,500	12,900	96	3	5
10	Miscellaneous	7.0	63,000	20,000	32	4	5
	Total	100.0	900,000	526,800	58		108

Appendix C-2

Conclusions for the Primary Industries

Technological Feasibility

Conclusions drawn from diverse industry segments generally have little value. In this case, however, such conclusions can reasonably be drawn, since many of the processing steps are similar, if not identical, and the problems for fiber release and control technologies employed are similar.

- The 10 primary industry segments have moved expeditiously to reduce worker exposure to airborne asbestos. Our study indicates that worker exposure was significantly reduced even before the 1972 standard was promulgated. Since adoption of the existing standard, further reduction in exposure has been achieved.

- The range of existing fiber counts reported by industry (Figure 2-1) indicates that 47.3 percent are between 0 and 2.0 fibers/cc TWA and that 52.7 percent are above 2.0 fibers/cc. Further, 9.7 percent have greater than 6.0 fibers/cc exposure. At process steps where the fiber source could be confined and available dust control equipment and technology could be implemented, fiber levels were reduced to a range of 1 to 2 fibers/cc TWA. There still remain large numbers of work stations and operations where readily available equipment was ineffective, where the dust source could not be confined or the nature of the operation inherently released fiber into the atmosphere, or where the dust source was beyond the control of the manufacturer (incoming fiber shipments). While significant progress has been made at these locations, levels of fiber exposure in the 2-6 fiber/cc TWA range still occur, with occasional fiber levels as high as 22 fibers/cc TWA.

- Considerable variation is experienced in fiber count readings at the same work station, using the same control equipment. Ranges as broad as 0-22 fibers/cc TWA have been reported. A major source of variation appears to be in the test method used to determine fiber count. Another significant source of variation in fiber count is the work practices and methods of the individual employee. Careful attention of the employee to work habits which minimize dust generation is a prerequisite to achieving and

maintaining lower exposure levels. On the other hand, poor work habits will increase fiber exposure regardless of the level of engineering control.

- A significant portion of the airborne asbestos results from materials handling, rather than directly from processing equipment. While such a distinction may appear small, it has a profound effect on the strategy of control and on the ultimate level of control achievable. In process sources, a point or points of fiber release can generally be controlled. When fiber release is due to handling the raw fiber or product, it represents an area source, rather than a point source, and is therefore much more difficult to control. An analogous situation occurs in air pollution control technology when dealing with point vs. fugitive dust sources.

- In the majority of industry segments, the two major fiber release areas are fiber introduction into the process and product finishing. The fiber introduction step often results in high airborne fiber concentrations because fiber accumulates on the outside of the bag during transportation and because the bag must be opened, dumped, and disposed of. All of these steps involve intimate handling of the raw fiber and exposure to loose fibers which may have accumulated from previous handling.

- Once the asbestos enters the processing equipment, control of the fiber release is generally good. Often water or binders are added, further reducing the potential for fiber release. The product finishing step involves the mechanical modification of the asbestos-containing product. When such modification requires abrasion, such as in sanding, sawing, etc. fiber will again become airborne.

- Few data on ceiling exposures are available. Contacts have reported their concern with the TWA standard, rather than the ceiling concentration standard; however, no data exist to support their contention.

- Implementation of BAT will not reduce TWA exposure to 0.5 fiber/cc at all processing steps in the primary segments. Only 30 of 86 (35 percent) identified work stations were projected to be at or below the proposed 0.5 fiber/cc TWA exposure standard. Therefore, 65 percent of the primary process steps are above 0.5 fibers/cc. The achievement of an exposure limit of 0.5 fiber/cc TWA is not feasible with the application of BAT for each process step.

- Application of BAT is projected to reduce TWA exposure to 2.0 fibers/cc TWA or less at all work stations in the

primary industries.

- Implementation of BAT in the primary industries will require three to five years, based on industry estimates and on the implementation of the compliance schedules required by the existing standard.

- There is little question that reasonable monitoring in the work environment is necessary to determine the level of worker exposure. However, there are several factors which affect the feasibility of such a program.

  - .. The results of our study indicate a widespread lack of understanding and misapplication of the TWA and ceiling exposure, and personal and area sampling test methods and calculations.

  - .. The accuracy and reproducibility of the test procedure must be questioned in light of the wide variations in TWA fiber count reported at the same worker station, employing the same control equipment. Duplicate samples taken simultaneously from the same employee have indicated substantial variation in fiber count. While other factors can logically be expected to affect fiber count (variations in day-to-day work practices, raw materials, background fiber levels), the sampling and counting procedure must be questioned.

  - .. At present, only 74 laboratories are accredited by the American Industrial Hygiene Association (16) or participate in HEW's National Institute for Occupational Safety & Health asbestos counting program (58). We did not estimate in detail the total number of samples which would require asbestos counting; however, it does not appear feasible for the 74 laboratories to analyze the hundreds of thousands of samples which will be required by the proposed standard.

Economic Impact

Capital Costs to achieve BAT, exclusive of previous capital expenditures, in 1975 dollars are estimated at $93,950,000 (Table 4-10) for nine of the asbestos industry segments. The Capital Costs to achieve BAT for the miscellaneous segment were excluded because the diverse responses from that segment were not amenable to further analysis. Concerning Capital Costs to achieve BAT, it should be noted:

.. BAT control equipment has already been installed at many work stations in order to meet the 2.0 fiber/cc TWA standard.

.. BAT will not achieve a uniform 0.5 fiber/cc TWA standard at all work stations.

.. In many installations, BAT will be achieved by modifying existing control equipment, rather than by installing new facilities.

Total Annual Costs to achieve BAT, exclusive of current annual costs, is estimated at $66,440,000 (Table 4-10). These costs include annual capital costs for control equipment, annual operating costs, and the annual industrial hygiene and medical program costs to the requirements of the proposed standard. However, the $66,440,000 is bsed upon only 9 segments (excluding Miscellaneous) nand is based on improving present operations to the BAT level, rather than meeting the 0.5 fiber/cc proposed level.

The Total Annual Costs as a Percent of Average Annual Sales for each segment range from 1.6 to 11.8 percent (Table 4-10). For most of these segments, the cost increase can likely be passed on to the consumer with little or no loss in the market, in the form of price increases. Historically, cost increases resulting from implementation of the existing standard have been passed to the consumer with no market loss. However, up to this time, these cost increases have been eclipsed by "double-digit" inflation over the past three years, and by a 30 percent increase in fiber cost during the last 18 months.

The Asbestos Textile and Friction Products segments are most likely to suffer market losses because of cost increases. Since the mid-1950's the Textile segment has faced severe cost competition from foreign producers. We cannot predict the extent, additional Asbestos Textile business will be lost to foreign competition because of implementation of the proposed standard. The Friction Products segment has also recently experienced foreign competition, primarily from Canada. Further loss of business can be expected, as prices for domestically produced friction materials will increase because of the cost of implementing the proposed standard.

The Expected Capital Costs as a Percent of Typical Total Capital Expenditures range from 23 to 316 percent (Table 4-10). Only two of the nine segments expect less than 100 percent (Floor Tile and Asbestos-Reinforced Plastics) to comply with the proposed standard, the other seven industry segments will be required to devote significant capital resources to implementing BAT. As previously indicated the BAT level is above the proposed 0.5 fiber/cc in many process steps.

Appendix C-3

Summary of Economic Impact

Primary Asbestos Industries, by Segment

	Capital Cost to Achieve BAT	Annual Costs to Achieve BAT			% Increase in selling Price from Implementation of BAT	Expected Capital Costs (Percent) Vs Typical Total Annual Capital Expenditures
		Operating Costs	Industrial Hygiene & Medical Program	Total Annual Costs		
Asbestos Paper	$ 5,100,000	$ 200,000	$ 4,010,000	$ 5,510,000	1.7	172
Asbestos Cement Pipe	12,000,000	750,000	2,150,000	5,900,000	3 2	162
Floor Tile	2,720,000	1,380,000	6,000,000	8,060,000	3.0	33
Friction Products	29,800,000	3,360,000	6,570,000	17,380,000	7.8	316
Paints, Coatings, and Sealants	4,230,000	550,000	2,730,000	4,340,000	1.6	143
Asbestos Cement Sheet	3,300,000	130,000	1,120,000	2,070,000	3.0	256
Gaskets and Packing	16,000,000	1,100,000	5,550,000	10,650,000	7.3	148
Asbestos Reinforced Plastics	1,100,000	110,000	2,310,000	2,690,000	2.4	23
Astestos Textiles	19,700,000	1,550,000	3,370,000	9,840,000	11.8	273
Overall Primary Industries	93,950,000	9,130,000	33,810,000	66,440,000[1]	5.1	

[1] Includes Annualized Capital Costs

Appendix C-4

Summary of Economic Impact - Secondary Industries

Industry Segment	Capital Cost to Achieve BAT (2)	Annual Costs to Achieve BAT: Operating Costs	Annual Costs to Achieve BAT: Industrial Hygiene and Medical (3) Programs	Total Annual Costs	Total Estimated Employment	Total Estimated Number of Establishments
Asbestos Paper	168,300,000	6,600,000	165,300,000	213,980,000	198,000	
Asbestos Cement Pipe	-	-				
Floor Tile	-	-				
Friction Products	794,300,000	91,160,000	1,673,700,000	1,963,440,000	2,004,500	
Paints, Coatings, and Sealants	-					
Asbestos Cement Sheet	20,400,000	800,000	20,000,000	25,900,000	24,000	
Gaskets and Packings	12,800,000	880,000	12,500,000	16,580,000	15,000	
Asbestos Reinforced Plastics	8,900,000	890,000	8,800,000	11,920,000	10,500	
Asbestos Textiles	6,400,000	500,000	6,300,000	8,400,000	7,500	
Miscellaneous	8,900,000	710,000(1)	8,800,000	11,740,000	10,500	
TOTALS	1,020,000,000	101,540,000	1,895,400,000	2,251,960,000	2,270,000	258,000

(1) Estimated at 8% of capital cost.
(2) BAT capital costs on Table 5-4, based on employment.
(3) From Table 5-4.

Appendix C-5

Summary of Economic Impact

Costs	Primary	Secondary	Consumer	Total
Capital Cost to achieve BAT	$93,950,000	$1,020,000,000	Not Required	$1,113,950,000
Total Annual Costs to achieve BAT (Annualized Capital + Operating + Industrial Hygiene and Medical Costs)	$66,440,000	$2,251,960,000	$1,652,000,000	$3,970,400,000
Industrial Hygiene and Medical Program vs Total Annual Costs (Percent)	51	85	100	89
Estimated Total Number of employees	37,500	2,270,000	11,800,000(2)	14,107,500
Estimated number of plant locations	190	258,000	140,000	398,190
Estimated increase in selling price for implementing BAT (percent).(1)	5.1	4.7	0.3	

(1) The values shown for secondary and consumer industry groups do not include the pass-through increases required to achieve BAT by the previous industry group.

(2) The total employment for this industry group may include employees from the primary and secondary industry groups.

Appendix D - Cost Data

Appendix D

Annualized Cost Calculation for a Friction Products Manufacturer*

I = 10%
Life = 8 years

	2 f/cc	1 f/cc	0.5 f/cc	0.1 f/cc
Capital cost	48,677	77,130	156,376	1,090,036
Installation cost	36,507	57,848	117,283	817,527
Engineering costs	4,868	7,713	15,637	109,004
Contingencies	4,868	7,713	15,637	109,004
Total Capital Cost	94,920	150,404	304,933	2,125,571
Annualized costs of capital	17,792	28,192	57,157	398,417
Maintenance & Bag Replacement	6,667	15,889	23,588	23,588
Fixed charges	1,545	2,534	5,259	5,259
Housecleaning	23,000	23,000	47,000	47,000
Operating cost (includes disposal of waste)	5,262	6,373	7,403	7,403
Air heating & Hydro	10,674	20,081	28,798	28,798
Loss in productivity	40,000	48,000	48,000	48,000
Laundry	4,765	4,765	4,765	4,765
Personal Protective Devices	5,029	5,029	5,029	5,029
Training Costs Monitoring & Medical	3,660	3,660	3,660	3,660
TOTAL ANNUAL OPERATING COST	118,394	157,523	230,659	571,919

Note: Details of calculations are on file at the University of Waterloo.
Annualized capital cost determined as follows:

(Total capital x capital recovery factor) = Annual cost of capital

*(Costs are in 1980 Canadian Dollars)

Appendix E - Personal Protective Devices

Table 1 - Type of Respirator Required*

The respiratory equipment provided by an employer and used by a worker shall meet or exceed the following requirements:

Type of Asbestos	Concentration	Type of Respirator Required
Chrysotile	Less than or equal to 5 fibres/cm^3 (5xTWA)	Reusable or replaceable filter-type air purifying dust respirator or single-use dust respirator
Chrysotile	Less than or equal to 50 fibres/cm^3 (50xTWA)	Powered air purifying positive-pressure dust respirator
Chrysotile	Greater than 50 fibres/cm^3 (50xTWA)	Positive-pressure supplied air respirator with full face piece.
Amosite, Crocidolite	Less than or equal to 1 fibre/cm^3 (5xTWA)	Reusable or replaceable filter-type air purifying dust respirator or single-use dust respirator
Amosite, Crocidolite	Less than or equal to 10 fibres/cm^3 (50xTWA)	Powered air purifying positive pressure dust respirator
Amosite, Crocidolite	Greater than 10 fibres/cm^3 (50xTWA)	Positive pressure supplied air respirator

Other types of Asbestos: See Chrysotile above

Note:
1. Respirators need not be worn if the levels of asbestos are less than a TWAEL of 0.2 fibres/cm^3 for crocidolite, 0.5 fibres/cm^3 for amosite or 1.0 fibres/cm^3 for any other types of asbestos. However, if the worker wishes to use a respirator below the TWAEL then the correct type of respirator must be worn.

2. Supplied air respirator does not include a powered air purifying respirator.

*Ontario Ministry of Labour, Occupational Health Branch. "Code for Respiratory Equipment for Asbestos." Mimeographed [Toronto]: September 21, 1981.

Table 2 - Personal Protective Devices

Typical Prices

Type of Device	Price Range ($)
Disposable and single-use respirators	1.50-15.00
Filter-type cartridge respirators	15.00-108.00
Cartridges	8.00-9.00
Air purifying helmets with Battery pack and charger	500.00
Positive Pressure supplied air Respirators:	
Portable	1,300.00-2,000.00
Stationary supply	250.00-300.00
Reusable coveralls	100.00-150.00
Disposable coveralls	6.00-15.00

Appendix F - List of Companies

Table 1

Asbestos Product Manufacturers in Ontario

(List taken from letter from Arthur L. Gladstone, Occupational Health and Safety Division to Linda Kahn, Executive Co-ordinator, Royal Commission on Asbestos, 29 June 1981, Toronto.)

	Comments
Abex Industries, Canadian Brakeblok Division 50 Colborne Street East Lindsay, Ontario K9V 4R8	Plant Visited 10/28/81
Able Gasket & Materials Limited 112 Snidercroft Road Concord, Ontario L4K 1B1	Plant Visited 10/29/81
Canadian Johns-Manville Company Limited 5421 Lawrence Avenue East West Hill, Ontario M1E 4S3	No longer manufacturing asbestos containing products in Ontario
Certified Automotive Products 1000 Martingrove Road Rexdale, Ontario M9W 4V9	Plant Visited 11/18/81
Durabla Limited 293 University Avenue Belleville, Ontario K8N 5B5	Plant Not Visited
Flextile Limited Box 251, Station "N" Toronto, Ontario M8V 3T2	Plant Visited 11/18/81
Garlock of Canada 66 Jutland Road Toronto, Ontario M8Z 2H3	Plant Visited 11/05/81
Hill Machine & Asbestos Products 365 Eddystone Avenue Downsview, Ontario M3N 1H8	Plant Visited 11/04/81

Holmes Insulations Limited P.O. Box 2079 561 Scott Road Sarnia, Ontario N7T 7L4	In telephone conversation with management it was learned company is no longer involved with asbestos
Insul-Coustics Limited 2766 Fenton Road Box 925, R.R. #5 Ottawa, Ontario K1G 3N3	Company indicated asbestos is not manufactured or handled
Mintex Federal, Scandura Canada Division 189 Rexdale Blvd. Rexdale, Ontario M9W 1P9	Plant Visited 10/29/81
Raybestos-Manhattan (Canada) Limited P.O. Box 959 944 Crawford Drive Peterborough, Ontario K9J 7A7	Plant Not Visited
Scott Laboratories 950 Brock Road South Pickering, Ontario L1W 2A1	Plant Visited 11/04/81
Universal Insulations Company P.O. Box 158 110 Connaught Avenue Aurora, Ontario L4G 3H3	Telephone contact with plant management - 12/17/81

Table 2

Supplementary List of Asbestos Product Manufacturers in Ontario Contacted for this Study

Acro Gasket Industries Ltd.	Rexdale
Albion A.A.P.Inc.	Toronto
Bakelite Thermosets	Belleville
Bendix Automotive	Windsor
Canadian Cylinder	Brantford
Cataract Canvas Ltd.	Niagara Falls
A.W. Chesterton Company Ltd.	Burlington
Chevron Asphalt	Toronto
Collingwood Shipyards	Collingwood
Inmont Presstite	Georgetown
Master Paint & Varnish	Hamilton
Niagara Paint & Chemical	Hamilton
Plough Canada Ltd.	Mississauga
Ranger Safety Products Ltd.	Simcoe
Relmech Manufacturing Ltd.	Elmira
Thompson-Gordon	Hamilton

Table 3

Companies Using Asbestos and Under Medical Surveillance by the Occupational Health Branch (Updated September 22, 1980)

(From Ontario Ministry of Labour, Appendices to the written submission to the Royal Commission on Asbestos, #43, February 1981, Appendix G, pp. 31-37):

NOTE: Many companies are past users of asbestos or use finished asbestos products only.

	Name of Company	Location	No. of Employees Exposed
	ZONE 1		
1.	Abex Industries	Lindsay	134
2.	Bakelite Thermosets	Belleville	20
3.	Branson Machine & Tool	Peterborough	10
4.	Canada Talc Ind. Ltd.	Madoc	26
5.	Canadian General Electric	Peterborough	150
6.	Dayton Tire	Whitby	86
7.	Durabla Canada	Belleville	11
8.	J.N.C. Limited	Ajax	41
9.	Ontario Gypsum Limited	Ajax	5
10.	Pennkote	Ajax	3
11.	Raybestos Manhattan	Peterborough	126
12.	Reichold Chemicals	Lindsay	6
13.	Scott Laboratories	Pickering	10
14.	Trent Rubber	Lindsay	143
	ZONE 2		
1.	Alcan Canada	Kingston	2
2.	Applied Insulation	Kingston	2
3.	Asbestonos Corp. Ltd.	Ottawa	6
4.	Genstar Chemical	Brockville	13
5.	Dupont of Canada	Maitland	19
6.	Industrial Moulders	Jasper	7
7.	Kingston Psychiatric Hosp.	Kingston	4
8.	Ontario Hydro	Ralphton	7
9.	Ottawa Perma-Coating	Ottawa	4
10.	Sadler, James & Son Canada Ltd.	Ingleside	15
	ZONE 3		
1.	Abitibi Paper Co. Ltd.	Iroquois Falls	75
2.	Alcan Canada Products	Bracebridge	22

Name of Company	Location	No. of Employees Exposed
3. Algoma Control Railway	Sault Ste. Marie	200
4. Algoma Central Railway	Hawk Junction	40
5. Algoma Steel	Sault Ste. Marie	2,500
6. Canadian Johns Manville	North Bay	7 ex-asbestos workers
7. Rufel Marble Products	Sault Ste. Marie	1
ZONE 4		
1. All Colour Paint & Chemicals	Oakville	6
2. Babcock and Wilcox	Burlington	16
3. Blast-Teck Limited	Oakville	7
4. Canadian Ferro Hot Tops	Stoney Creek	27
5. Canadian Meter Co. Ltd.	Milton	22
6. A.W. Chesterton Company	Burlington	2
7. Crane Packing	Stoney Creek	16
8. Currie Products	Hamilton	9
9. Dofasco	Hamilton	200
10. Endur Environment	Burlington	8
11. Hamilton Match Plate	Hamilton	7
12. Inmont Presstite	Georgetown	7
13. Kaiser Refractories	Oakville	37
14. Master Paint & Varnish	Hamilton	2
15. Niagara Paint & Chemical	Hamilton	6
16. Plastics & Asbestos Products	Hamilton	14
17. Plibrico Canada	Burlington	39
18. Provincial Brake & Clutch Service Ltd.	Hamilton	2
19. Rheem Canada Limited	Hamilton	30 ex-asbestos workers
20. Robert Soper Limited	Chatham	11
21. Thompson-Gordon	Hamilton	15
22. Westinghouse Canada Ltd.	Hamilton	20
ZONE 5		
1. Canadian Cylinder	Brantford	19
2. Canadian Gasket	Fort Erie	50
3. Canadian Gypsum	Hagersville	294
4. Cataract Canvas Limited	Niagara Falls	22
5. Domtar Construction	Brantford	70
6. Domtar Construction	Caledonia	190
7. General Motors of Canada	St. Catharines	1,780
8. Hamilton Porcelains Ltd.	Brantford	79
9. Harding Carpet Limited	Brantford	40

Name of Company		Location	No. of Employees Exposed
10.	Bondex International	Bramalea	39
11.	Mott Manufacturing	Brantford	19
12.	Niagara Protective Coatings	Niagara Falls	9
13.	North American Refractories	Caledonia	12
14.	Ontario Hydro	Nanticoke	
15.	Pratt and Lambert	Fort Erie	36
16.	Scarfe and Co. (Inmont Canada Ltd.)	Brantford	13
17.	Sterling Varnish	St. Catharines	40
	ZONE 6		
1.	Able Gasket	Weston	16
2.	Acro Gasket Ind.	Rexdale	23
3.	Albion A.A.P. Inc.	Toronto	10
4.	Aluminum Goods (Alcan)	Toronto	54
5.	Amalgamated Electric	Markham	6
6.	Apco Industries	Toronto	6
7.	Asbestos Building Supplies	Toronto	10
8.	Asbestonos Corporation	Toronto	8
9.	Benjamin Moore & Co. Ltd.	Toronto	50
10.	Bondex International	Bramalea	4
11.	C.I.L. Paints	Concord	89
12.	Canada Colours & Chemicals Ltd.	Brampton	11
13.	Canada Varnish (CVI Paints)	Toronto	15
14.	Canadian Asbestos Ontario	Toronto	9 ex-asbestos workers
15.	Canadian Coleman	Etobicoke	39
16.	Canadian General Electric	Toronto	190
17.	Canadian Gypsum Co. Ltd.	Toronto	60
18.	Canadian Industries	Toronto	36
19.	Canadian Johns Manville	Toronto	
20.	Canadian Johns Manville	West Hill	500 no longer manufacturing asbestos-containing products
21.	Canadian Rockwell Co. Ltd.	Toronto	22
22.	Cantire Products Limited	Toronto	78
23.	Central Precision	Rexdale	20
24.	Chembond Limited	Mississauga	13
25.	Chevron Asphalt	Toronto	8
26.	Childers Products Co. Ltd.	Mississauga	3
27.	Crupi, D. and Sons Ltd.	Agincourt	5
28.	Colour Your World Inc.	Toronto	8
29.	Crouse-Hinds Canada Ltd.	Scarborough	72
30.	Crowle Fittings Limited	Brampton	3
31.	Desota Coatings	Toronto	17

Name of Company	Location	No. of Employees Exposed
32. Downs wood Limited	Toronto	17
33. Dupli-Color (Canada) Ltd.	Scarborough	23
34. Electrolyser Corp.	Etobicoke	38
35. Erico Inc.	Toronto	10
36. Flintkote Co.	Toronto	105
37. Fuller H.B. Canada Inc.	Mississauga	2
38. Garlock of Canada	Toronto	50
39. Gibson-Holmans	Toronto	9
40. Goodyear Canada Inc.	Toronto	136
41. Gulf Canada Products	Mississauga	9
42. Hemispheres International	Downsview	55
43. House of Sturgeon (Chemicals Ltd.)	Weston	11
44. IBIS Products Ltd.	Scarborough	13
45. Industrial Coating Co.	Weston	5
46. K.G. Packaging	Concord	11
47. Knecht Berchtold Limited	Brampton	19
48. Lee Chemicals	Toronto	1
49. LePage's Limited	Bramalea	129
50. Lever Detergents	Toronto	11
51. Liquid Carbonic Canada Ltd.	Scarborough	110
52. Markham Sand & Gravel Ltd.	Buttonville	4
53. Masse Manufacturing	Toronto	2
54. Miller Paving	Toronto	3
55. M.S.A. Canada	Downsview	22
56. Mintex Canada Ltd.	Rexdale	83
57. Mobil Chemical Canada Ltd.	West Hill	83
58. Monleith, A.R. (77) Ltd.	Mississauga	14
59. National Health & Welfare (re: Toronto International Airport)	Toronto	18
60. North York Board of Ed.	Willowdale	35
61. Ontario Hydro	Toronto	60
62. Ontario Hydro	Port Credit	110
63. Ontario Reman	Rexdale	3
64. P.P.G. Industries Canada Ltd.	Mississauga	80
65. P.P.G. Industries Canada Ltd.	Toronto	130
66. P.R.C. Chemical Corp. of Canada Ltd.	Weston	25
67. Parr Industries Limited	Weston	11
68. Para Paints Limited	Rexdale	42
69. Pattern Matchplate Inc.	Downsview	8
70. Professional Texture System Inc.	Markham	8
71. Repac Const. & Materials	West Hill	5

Name of Company		Location	No. of Employees Exposed
72.	Royal Industries (Certified Brakes LSI Industries)	Rexdale	316
73.	Safeco Manufacturing Ltd.	Scarborough	16
74.	Seiberling Canada Ltd.	Toronto	300
75.	Selectone Paints Ltd.	Weston	35
76.	Sommerville Belkin Industries Ltd.	Scarborough	72
77.	Swingline of Canada Ltd.	Toronto	4
78.	Tempo Paint & Varnish Co.	Weston	12
79.	Texas Refinery Corp. of Canada Ltd.	Toronto	4
80.	Toronto Hydro	Toronto	60
81.	Tremco Canada Ltd.	Toronto	120
82.	Trend Coatings Ltd.	Weston	14
83.	Universal Sealants Ltd.	Toronto	2
84.	Viceroy Manufacturing Co. Ltd.	Toronto	180
85.	S.K. Wellman of Canada Ltd.	Concord	10
86.	D.A. White Co. Ltd.	Toronto	2
87.	Wilkinson Foundry Facing and Supply Ltd.	Toronto	22
	ZONE 7		
1.	Collingwood Shipyards	Collingwood	25
2.	Nor-Var Paints	Owen Sound	3
3.	Ontario Hydro	Tiverton	114
4.	P.P.G. Industries Canada Ltd.	Owen Sound	15
	ZONE 8		
1.	Almatex Limited	London	114
2.	Cleaver Brooks	Stratford	5
3.	Durametallic of Canada Ltd.	St. Thomas	23
4.	Firestone Textile Company	Woodstock	25
5.	Hayes Dana Parts Co. Ltd.	St. Thomas	33
6.	Ingersoll Machine & Tool Co. Ltd.	Ingersoll	120
7.	Ranger Safety Products Ltd.	Simcoe	34
8.	Richard Wilcox of Canada Ltd.	London	273
9.	Tobac Curing Systems	Simcoe	2

Name of Company	Location	No. of Employees Exposed
ZONE 9		
1. Bendix Automotive of Canada Ltd.	Windsor	**480 plant closed 1980
2. Byer's Truck & Trailer Equipment Ltd.	Windsor	2
3. Holmes Insulation	Sarnia	23
4. Inmont Canada Ltd.	Windsor	57
5. James & Carter Automotive	Sarnia	12
6. Ontario Hydro	Courtright	78
7. Southern Wood Products Ltd.	Petrolia	33
8. Welles Corporation	Windsor	75
ZONE 10		
1. Clare Brothers	Cambridge	5
2. Foseco Canada Limited	Guelph	34
3. Franklin Manufacturing	Cambridge	13
4. B.F. Goodrich Co. Canada Ltd.	Kitchener	194
5. H.D. Pattern & Matchplates Inc.	New Hamburg	7
6. Korzite Industries Ltd.	Guelph	12
7. Pirelli Cables Ltd.	Guelph	3
8. Relmech Mfg. Limited	Elmira	38
9. Silcofab Ltd.	Guelph	52
10. St. Jacobs Canning	St. Jacobs	8
11. Tracon Engineering Ltd.	Waterloo	16
12. Uniroyal Chemical Division of Uniroyal Limited	Elmira	217
13. Walker Exhausts Limited	Cambridge	66

**"Based on number of employees offered health screening and not necessarily representative of number of employees actually exposed to asbestos" according to communication from Bendix Automotive.

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Royal Commission on Matters of Health and Safety Arising from the Use of Asbestos in Ontario

180 Dundas Street West
22nd Floor
Toronto, Ontario
M5G 1Z8
416/965-1885

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ISBN:0-7743-7311-3 Printed in Canada (7C/04/82)

ISBN: 0-7743-7311-3 Printed in Canada (7C/04/82)